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A SURVEY OF THE RECREATIONAL RESOURCES OF THE COLORADO RIVER BASIN

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A SURVEY OF THE RECREATIONAL RESOURCES OF THE COLORADO RIVER BASIN

UNITED STATES DEPARTMENT OF THE INTERIOR
OSCAR L. CHAPMAN, *Secretary*

NATIONAL PARK SERVICE
NEWTON B. DRURY, *Director*

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UNITED STATES DEPARTMENT OF THE INTERIOR

NATIONAL PARK SERVICE

A SURVEY OF THE RECREATIONAL RESOURCES OF THE COLORADO RIVER BASIN

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A SURVEY OF THE RECREATIONAL RESOURCES OF THE COLORADO RIVER BASIN

Figure 1.—View west over Colorado River to the Orange Cliffs and the Henry Mountains.

FOREWORD

Most rivers are friendly to man; they are arteries of commerce and their valleys are centers of industrial and agricultural activities, but the Colorado is a hindrance rather than an aid to travel and transportation. For about 80 percent of its course, the river is cliff-bound and most of the tributary channels are deep and narrow, ideal for the construction of dams for water storage but not readily adaptable to gravity distribution of stored water for irrigation purposes in the immediate vicinity. In area, the Colorado River Basin comprises 8.7 percent of the United States, but contains only 0.7 percent of the population. Successful farming and fruit raising, development of the tourist industry, and the future growth of the basin depend upon the wise use of its water and other resources, including the preservation of its scenic character and appropriate development of its recreational possibilities. The snow and rain that fall in the Wind River Mountains in Wyoming and the Rocky Mountains in Colorado may help to water a melon patch near Yuma, Ariz. Wise utilization of all resources of the basin requires careful and thorough study of all their potentialities so that the best possible use may be made of them in providing a good life for the people within the basin and for the benefit of the Nation as a whole.

The Colorado River Basin includes desert and mountains, canyons and high plateaus. Among the great resources of the basin are its scenic, scientific, historic, and recreational features. With the growth and development of the Nation, interest in these features is increasing rapidly. This is particularly true with regard to recreation which is one of the fundamental necessities of human life, taking its place with health, spiritual and economic well-being, and work as basic requirements for balanced living. The economic welfare of the basin will depend largely upon its agricultural production, but the adequacy of the recreational facilities within the basin will be an important factor toward increasing and maintaining this production at a high level. In addition, adequately developed recreational facilities will attract tourists and thereby further enrich its economy. In this connection, the preservation of great natural areas like Grand Canyon and Zion National Parks for the use and enjoyment of the people for all time is of inestimable value. While Hoover Dam was constructed primarily for the benefit of the people living within the basin, a substantial benefit is carrying over to adjoining areas. For example, the power generated has made possible the establishment of large industries in southern California and the people brought in by these industries are turning to Lake Mead and other places in the Colorado River Basin for recreation.

In order that the recreational resources may receive consideration in planning and development of the basin, the National Park Service has made the survey recorded in this report.

Oscar L. Chapman

Secretary of the Interior.

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INTRODUCTION

Section 2 (d) of the Boulder Canyon Project Adjustment Act of July 19, 1940, provides authority for financing conservation investigations and studies in connection with the work of the Bureau of Reclamation within the Colorado River Basin.

The Bureau of Reclamation, in November 1940, under the authority of the Adjustment Act, requested the National Park Service to identify the scenic, scientific and recreational resources of the Colorado Basin, as a part of a comprehensive plan for the utilization of the water resources of the region.

Since its establishment in 1917, the National Park Service has been concerned with these resources. At the present time it administers several areas directly affected by the developments planned by the Bureau of Reclamation.

On January 27, 1941, the Secretary of the Interior approved the inclusion of a basin-wide recreational survey as a part of the studies and investigations to be continued and extended under his direction for the formulation of a comprehensive plan of utilization of the waters of the entire Colorado River System. The Secretary also appointed Frederick Law Olmsted, distinguished landscape architect, with wide experience in regional and site planning, as consultant for the survey.

The principal purpose of the survey was to obtain the facts essential to the establishment of Departmental policies regarding classification, development and administration of possible water-control projects and areas within the basin, giving due regard to recreational possibilities and the presentation of scenery and other natural features.

The survey also embraced the study of recreational resources of large portions of the basin which are not administered by the Department. Information thus gained will be helpful to the Bureau of Reclamation in avoiding needless sacrifices of existing and potential recreational values, and in utilizing opportunities to obtain recreational benefits as an incident to the development of water resources.

Another purpose of the survey was to identify and evaluate such areas as might be of outstanding national importance, so that measures may be taken to maintain them in a high state of preservation for public enjoyment. This study was not exhaustive. An attempt to enumerate and evaluate all types of recreational resources, both existing and potential, throughout the entire basin, would have been a huge undertaking beyond the scope of the survey.

The National Park Service first focused its attention on areas in which the most pressing problems occur, namely, Dinosaur National Monument, the Grand Canyon area, and the Canyon Lands of southeastern Utah. The work was done by the Branch of Lands (now the Land and Recreational Planning Division) of the Service, headed by Conrad L. Wirth, with Mr. Olmsted as consultant. Field headquarters of the survey were established in the National Park Service Region Three Office in Santa Fe, N. Mex. with one member of the field staff assigned to the Region Two Office in Omaha, Nebr., to cover problems falling within that region. Frequent consultation with Bureau of Reclamation officials was the rule. Valuable assistance was given by the Grazing Service (now included in the Bureau of Land Management), the Fish and Wildlife Service, the Bureau of Indian Affairs, and the Geological Survey, as well as many other Federal and State agencies and private individuals. Appreciation is expressed to Dr. Herbert E. Gregory and Edwin D. McKee for their collaboration in the preparation of the chapter on the geology of the

basin, and to Dr. Emil W. Haury, Dr. Gordon C. Baldwin, and Dr. Jesse L. Nusbaum for their collaboration in the preparation of the chapter, Prehistory of Man. Appreciation is also expressed to the many individuals listed on page 223, who generously contributed their time and special knowledge in checking various portions of the life zone map and the biological information presented in the text.

Although the report is dated June 1946, a few minor revisions in the original draft have been made subsequently in order to include later information, such as revised height of proposed dams and the redesignation of Boulder Dam as Hoover Dam and Boulder Dam Recreational Area as Lake Mead Recreational Area.

NEWTON B. DRURY, *Director,*
National Park Service.

SUMMARY

The Colorado River Basin is one of the outstanding recreational regions in the United States because of its great variety of natural scenery, climatic conditions, areas and objects of scientific interest, abundant evidence of prehistoric occupation, and present Indian, Spanish, and Anglo cultures. Here one may enjoy a large amount of sunshine and find perfect climates and settings for various types of outdoor recreation the year around. The basin embraces latitudes from Mexico almost to Yellowstone National Park and altitudes ranging from 248 feet below sea level to 14,431 feet above sea level. All of the life zones of the United States are present except the Tropical Life Zone of southern Florida.

Geologic features.—An unusual feature of the basin is the peculiar alinement and local setting of the drainage channels, glaringly out of accord with the topography, exemplified by the mile-deep Grand Canyon through the Kaibab Plateau and Split Mountain Canyon. The central part of the Colorado Basin is unique in geologic history, topographic form, and scenic grandeur. Within it are displayed the oldest and youngest rocks exposed on the North American Continent. Major subdivisions of the geologic time scale are represented in orderly succession.

The Uinta Mountains and Uinta Basin are unique in the United States in that they trend east-west in contrast with the general north-south alinement of similar features elsewhere. The Uinta Basin is a famous source of fossils, and derives additional interest from its scattered outcrops of solid hydrocarbons, including rare forms, some of them unique and little understood. The outstanding features of the Colorado Plateau are the widespread Triassic, Jurassic, and Cretaceous strata in approximately horizontal position; the gigantic cliffs of different geological ages and marked by distinctive colors; and the multitude of canyons that carry the perennial, intermittent, and ephemeral run-off. In places, the surface has been roughened by folding, faulting, the building of volcanoes, and the intrusion of igneous rocks.

Bordering the Colorado Plateau on the east is a belt of tangled topography developed on rocks complex in structure, composition and relationships. The landscape is characteristic of the Rocky Mountains rather than the plateau country.

The Prescott, Ariz., area is significant in that great ore bodies have been brought up by faulting. Many mines have been developed in this region. The asbestos deposits that appear as conspicuous white lines from a distance are an outstanding geologic feature of the Sierra Ancha Mountains in central Arizona. Similar asbestos deposits are found in the Salt River Canyon.

The Verde Hot Springs, Soda Springs, fossil trackways of prehistoric mammals, salt deposits, prehistoric salt mines, and lake deposits with mollusks are important features of the Verde Valley.

The San Francisco Mountains, the White Mountains, and, to a lesser extent, the Mount Trumbull region are areas of geologically recent volcanic activity which have so modified both the appearance and character of the country as to merit special attention.

The lower portion of the basin, below the great plateau region, is totally different from that to the north. Rugged mountain ranges rise out of broad, flat valleys like islands in the sea. The mountains contain rocks of many geologic ages and their structural histories are complex.

The delta of the Colorado River is formed in, and is controlled by, one of the most remarkable and unique structural troughs in the earth's surface. It is a depression comparable to the trough of the Dead Sea and Jordan Valley in Palestine.

Events representing the history of the earth undoubtedly are more closely and simply illustrated by the record of the rocks in the Colorado Plateau than anywhere else in the world. In order that this history may be skillfully presented to visitors, emphasis must be placed on original materials. Facts must be dealt with and presented in a way that will guide people's thoughts toward a realization of the principles. The task is to lead people to the best

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possible illustrations through the skillful development of roads and trails and to make available data necessary to a correct interpretation and correlation of facts.

Plants and animals.—Plants and animals are dependent upon one another in a manner so complex and far reaching that they cannot be fully enjoyed or protected separately. Without plants there can be no cool, clear trout streams; no shady camping spots; no fertile, humus-bearing soil; no food for other forms of life. Recreational enjoyment of plants ranges from subconscious appreciation of their beauty and shade to active interest and wonderment at the marvelous diversity of plant forms which results from their adaptation to extremes of climate and environment. The recreational value of animals is indicated by the fact that by 1945, in spite of wartime restrictions, 20 million anglers and hunters spent 2 billion dollars per year in pursuit of their sport. But fishing and hunting are only two of the many recreational values of wildlife.

Originally the basin had a much greater wealth of vegetation and wildlife than at present. Many desert watercourses that present generations are accustomed to think of as dry washes or as intermittent streams once flowed the year around. The more luxuriant vegetation of those days checked the runoff from the storms more efficiently than it is checked at present. After 1870, cattle increased greatly in the desert regions and the forage thinned and disappeared. Trampling hoofs stripped the thin protecting layer of decaying plant materials from the surface of the soil and as a result plant growth changed or disappeared and animal life was starved out. Animal life in the mountains has undergone a corresponding decrease as a result of direct persecution, as well as from forage and habitat depletion.

Another cause of depletion of wildlife has been the occupancy of most of the choice, fertile regions by cities and farms. Elk, deer, beaver, turkeys, and many wild creatures, today considered to be almost exclusively mountain dwellers, originally had their centers of abundance, particularly during the winters, in the lower hills and adjacent valleys.

The decline of wildlife reached a low in the late 1920's. Since then, vigorous conservation efforts have partially restored some species. The viewpoint that wildlife is a direct product of the land, to be increased by restoring the appropriate environment and growing conditions, and, where desired, to be harvested according to a definite plan, with a definite financial return like any other crop, was first emphasized during the early 1930's. This concept had wide appeal and has enlisted support for conservation efforts. Restoration has commenced but lags behind knowledge. Today millions of tons of soil continue to wash away needlessly. In the Southwest proper, grazing capacity has long since been exceeded and vegetation is far from adequate to protect the surface against erosive forces.

Grazing is a major basin industry that needs stabilization.

The problem of determining the proper uses of the Colorado River Basin is largely one of conserving its basic soil and water. In general, the present economic use pattern seems well adapted to the land. The principal need is to replace destructive methods by up-to-date ones with respect to existing land uses. The public is uninformed regarding basic conservation issues largely because conservation education has lacked focus. More support is needed for conservation education.

Archeologic features.—The Colorado River Basin contains abundant evidence of prehistoric occupation and use by man. Exploring the ruins and learning the dramatic story of these early peoples is one of the important recreational activities in the basin. The evidence of prehistoric settlement and use of the lands and waters constitute a resource of recreational and historical significance of unique and irreplaceable value to the Nation.

A considerable part of the archeological wealth of the Southwest is concentrated in valleys adjacent to adequate water supply and tillable fields. The construction of dams and flooding of river valleys will destroy thousands of these prehistoric and historic ruins. To offset this potential loss, there is a definite and immediate need for a well-planned and coordinated archeological program that will include specific recovery measures. The program should include (1) a careful archeological survey of each dam and reservoir site; (2) excavation of important archeological sites; and (3) thorough laboratory study and adequate publication of the scientific data.

Factors determining the recreational values of reservoirs.—In the arid portions of the basin, the

creation of large artificial lakes on reservoirs is of great recreational importance. The higher portions of the basin are fairly well supplied with clear streams and small lakes. The recreational value of a reservoir is dependent to a large extent upon its location, accessibility, the population of the area served, the nature of the reservoir site, and the plan of operation of the dam. The amount of fluctuation of water-surface area and elevation are major factors determining the recreational value of reservoirs, although water temperatures and the fertility of the reservoir sites have an important bearing on aquatic life within them.

Potential reservoir sites.—The survey covered about 135 potential reservoir sites. The recreational potentialities of these sites will be considerably increased in a number of cases—particularly the smaller reservoirs—if a dead storage or conservation pool can be assured. A number of reservoirs are proposed in locations where the existing natural features are of greater recreational value than can be expected of the proposed reservoirs. The majority of the proposed reservoirs, however, will create new recreational resources benefiting the basin.

Grand Canyon region.—The proposed Bridge Canyon Dam in the Grand Canyon will create a lake 93 miles long at a maximum surface elevation of 1,876 feet. Construction of the dam at the proposed elevation would amount to virtual disestablishment of Grand Canyon National Monument and, in addition, would back up water into Grand Canyon National Park for a distance of about 18 miles. The National Park Service deplores this proposal because for an exclusively economic gain it would substantially alter natural conditions and injuriously affect the natural scenery along the Colorado River as far as the backed-up water would extend. At the same time it is recognized that, even under the present plans for Bridge Canyon Dam, the major portion of Grand Canyon National Park would remain in its natural state. It is realized also that some persons will regard the damage to the natural features partially mitigated by the water recreational opportunities that will accrue. The National Park Service does not believe that these recreational benefits are sufficient to compensate for the loss of natural values and has urged that any dam constructed be at a lower level.

A dam at the Marble Gorge site might not be objectionable from the scenic and recreational viewpoint. In fact, a high dam at that site, which would eliminate a dam at the Glen Canyon site, might create a reservoir more adaptable for recreational development and use than a low dam at the Marble Gorge site and a high dam at the Glen Canyon site. On the other hand, the proposed diversion of Colorado River water around Grand Canyon National Park, by a tunnel through the Kaibab Plateau, in order to obtain the benefit of the fall of the Colorado River through the park would be extremely objectionable because it would eliminate the flow of the Colorado River through the most spectacular portion of the Grand Canyon which it formed.

All sections of the Grand Canyon are parts of one great physiographic unit. Man-made boundaries mean little as to the relative value of different portions. From the standpoint of the American people as a whole, it is important that the entire Grand Canyon and the bordering portions of plateaus be protected and that appropriate sites be developed for recreation, primarily of the inspirational type. The extension of opportunities to use Grand Canyon, especially the little-known western part, would greatly help in solving the future problem of adequate space for meeting the recreational needs of an increasingly large group. If water-control facilities are constructed in the Bridge Canyon area, the Peach Spring-Diamond Creek area, Granite Park, and the Toroweap-Whitmore Wash area, it appears that they will be suitable places for future major recreational centers in the Grand Canyon.

Canyon Lands of southeastern Utah.—The area comprising the Canyon Lands of southeastern Utah, part of the largest section in the United States without improved roads and one of the least known, is a region of the unusual in color and form; of great natural bridges, monuments, spires, deep twisting canyons, mammoth terraces with sheer walls a thousand or more feet high, and rock forms that resemble huge castles and cathedrals. It is a vast unoccupied area of great potential recreational value.

Two dams are proposed, one at the Dark Canyon site, the other possibly at the Glen Canyon site 4 miles above Lees Ferry in Arizona, or at an alternate site 15 miles above Lees Ferry. The combined length of both impoundments along the Colorado River would be 279 miles through the Canyon Lands. Although the reservoirs would eliminate for

the few the thrills of boating down the untamed river and reduce the apparent depths of the river canyons, they would be confined in the canyon of the Colorado and Green Rivers and have little, if any, effect on the great recreational resources of the region. Instead, the reservoirs would provide a means of access for many to see the wonders of the canyons.

The area is large enough and varied enough to permit the continued use and development of its resources—water power, minerals, forage, and recreation. Except in certain limited sections where a single use is essential to obtain the greatest benefits, these resources can be developed and used simultaneously.

The most important recreational sections of the Canyon Lands of southeastern Utah are the Grays Pasture–Junction Butte area, the Elk Ridge–Needles area, the Lands End area, the Hole in Rock area, the Hite area, the Wahweap area, the Goosenecks of the San Juan River, the Arch Canyon area, and Fisher Towers. Certain parts of these areas which contain known features of national importance should be withdrawn to afford them proper protection.

Dinosaur National Monument.—This monument was established in 1915 to preserve a rich deposit of fossilized dinosaur bones. In 1938, it was extended to include other resources of scientific interest found in the adjoining canyons of the Green and Yampa Rivers. Functionally, the monument now consists of the Quarry Unit, comprising three or four thousand acres, and the Canyon Unit, consisting of about 206,000 acres.

Two dam sites for utilizing the water resources of the Green and Yampa Rivers—the Echo Park and Split Mountain—are located in the monument. Construction of dams at these sites would adversely alter the dominant geological and wilderness qualities and the relatively minor archeological and wildlife values of the Canyon Unit so that it would no longer possess national monument qualifications. The Echo Park project would not affect the Quarry Unit. At the time this report was prepared, data were not available to determine whether the proposed pressure tunnel from Split Mountain Dam to a power plant on the Green River would affect the Quarry Unit.

The policy of the National Park Service, as the administrative agency now responsible for Dinosaur National Monument, is to make the protection of the natural and archeological values of the area the controlling factor in administering it. Before authorization is given to develop the water resources of the monument and to recognize water use as the principal consideration in the administration of the Canyon Unit, it should be clearly shown (1) that the economic and social values of such development will exceed the costs of producing them; (2) that it would be more economical to develop the water resources of the monument rather than some other resources available for the same purpose within practicable reach; and (3) that it would be of greater benefit to the whole Nation to develop the area for water storage and power than to retain the monument in a natural state for the enjoyment of all the people.

Conservation of recreational resources—The Colorado River Basin lies directly across all lines of travel between the rapidly increasing population of California and the densely populated eastern half of the United States. In the past the basin was to a large extent considered just a vast space that had to be crossed on the way to California. Now, with the Pacific Coast more fully developed, people seeking undeveloped, uncrowded areas are beginning to discover the basin. It is time for immediate action which will assure the preservation of its many and varied recreational features. It is also time to develop facilities which will enable people to see and enjoy the region. There are natural limitations on the amount of land that can be placed under cultivation. There is a limit, already reached in most sections, on the number of domestic animals that can be grazed. But the possibilities for the development of the recreational use of the basin are almost unlimited.

Some of the more important areas that should be preserved and made available for recreation are the western slope of the Wind River Range in Wyoming; the San Juan–San Miguel–Uncompahgre Mountain area, White River Plateau, the Elk Mountain area, and the Park Range in Colorado; the Uinta Mountains, the Aquarius Plateau–Boulder Mountain area, Monument Valley, and the Canyon Lands of southeastern Utah; the Gila primitive area and Manuelito area in New Mexico; Meteor Crater, Fort Bowie, the Blue Range area,

Mount Baldy–White Mountains area, the San Franciscan volcanic field, the Mogollon Rim area, Travertine Bridge, and the Kofa Mountains in Arizona; and Palm Canyon in California. Nationally significant archeological sites that should be permanently preserved are Poncho House in Utah; and Kinishba Ruins, Clear Creek Ruins, Chaves Pass Ruins, and Awatovi in Arizona.

To preserve the great areas of open country free of scattered reminders of city life and to maintain and stimulate the economic life of existing communities, it is recommended that facilities for the accommodation of travelers and vacationists be concentrated near existing towns and villages. Many towns are now focal points for recreational use of the surrounding country. This condition should be encouraged and developed.

While it will be necessary, in developing the resources of the basin, to construct new roads and improve existing ones and to construct other facilities, it must not be forgotten that among the basin's greatest recreational assets are the large areas in which there are no roads or other developments. Some roadless areas have been established, others are needed.

U S DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
COLORADO RIVER BASIN RECREATIONAL SURVEY
MAP SHOWING
LOCATION AND EXTENT OF BASIN

DRAWN BY JOHN E. KELL MAY 1944

RS-CRBR-710

The Colorado River Basin

GENERAL DESCRIPTION

From Gannet Peak in the Wind River Mountains of Wyoming and the 14,000-foot mountain peaks in Colorado to the Salton Sea in southern California, 248 feet below sea level, stretches the vast region of forests, deserts, plains, mountains, canyons, and plateaus drained by the Colorado River.

The outline of the Colorado River Basin as it follows the crests of adjacent mountain masses is irregular, but its general shape may be compared with the ear of a horse. The lower end of the basin in southern California, Arizona, and New Mexico, corresponding to the base of the ear, is broad, being some 500 miles wide at one point, and is bounded for the most part by low, desert ranges. Northward, in Utah and Colorado, the basin becomes progressively narrower, edged by loftier mountain ranges, until at the extreme northern tip of the ear, 830 miles from the Mexican border, it is reduced to a width of 25 miles as it culminates in the magnificent Wind River Range of western Wyoming.

The Colorado River Basin not only is ringed with mountains but contains within its boundaries many extensive ranges and lofty plateaus. In the north, these interior ranges run in an east-west, or else a northwest-southeast direction, forming a series of more or less parallel mountain barriers and high plateaus across the basin. Between these barriers lie great valley systems, also running more or less east and west. Only the mighty Green and Colorado Rivers have cut deep gorges in a southerly direction through the barriers to unite all the streams into one drainage. Toward the south, the interior ranges pivot gradually from the northwest-southeast direction, until in southern Arizona, Nevada, and New Mexico they run nearly north and south. The physiography of the basin can be most readily described in terms of these various mountain barriers and their intervening valleys.

Farthest to the north lies the spacious but bleak valley of the southward-flowing Upper Green River in Wyoming, with the elevated and still more barren Red Desert to the east. These areas have long, cold winters and short, dry summers. They extend south into northern Utah and Colorado where they encounter the first of the mountain barriers. This barrier is formed by the Uinta Mountains and Yampa Plateau as they extend eastward toward, but do not quite meet, the Danforth Hills and White River Plateau—which in turn are westward extentions from the main Rocky Mountain Divide. Winters are still longer and colder than in the valleys, with a heavy snowfall. Summers are cool, with frequent afternoon thunderstorms.

Beyond this first barrier to the south lies the broad, east-west valley of the Duchesne River, elevated and bleak, but farmed, and its counterpart on the opposite side of the Green River, the wilder but similar valley of the White River. These valleys have long cold winters and short dry summers like the Upper Green River Valley. They are bounded on the south by the second mountain barrier, comprising the Tavaputs Plateaus which, with the Roan Plateau, form an 8,000- to 9,000-foot wall all the way across the basin from the Wasatch Mountains on the west to the White River Plateau of the Rockies on the east. Only the Green River has been able to cut a cleft through this wall to join with the stream systems still farther south. The climate of this mountain barrier resembles that of the first, being characterized by deep, long-lasting winter snows and cool summers with afternoon thunderstorms.

About 50 miles south of the Tavaputs-Roan Plateau barrier, the southward-flowing Green River joins the Colorado River which, with its great tribu-

Figure 2.—The Wind River Mountains of Wyoming.

Figure 3.—Looking down the Green River Valley from La Barge, Wyo.

tary, the Gunnison, flows southwest from the heart of the Rockies through broad sagebrush valleys to this junction point. The Colorado River beyond this junction plunges into a wild and fantastically eroded land of winding gorges and sandstone mesas whose vast expanses are punctuated at irregular intervals by the isolated, steeply upthrust masses of the Henry, Abajo, and Navajo Mountains. With the exception of the mountain summits, which are cool and moist, the greater portion of the area receives but little snowfall in winter and is characterized by a long, warm summer season. Average temperatures are higher than those of valleys to the north, in conformity with the decrease in latitude, but lower than those of deserts to the south. The annual precipitation ranges from about 6 to 14 inches, with the greatest amount coming from thunderstorms during July and August.

This desolate but spectacularly scenic sandstone area is referred to in this report as the Canyon Lands of southeastern Utah. Into it from the east, through a deep meandering gorge, flows the turbid San Juan River which, with its tributaries, drains a far-reaching area, including the La Plata Mountains, the San Juan Mountains and other lesser ranges on the Continental Divide, the Chuska Mountains, and enormous areas of mesa land in the interior of the basin. From the Wasatch and Aquarius Plateaus on the west come other, but lesser, silt-laden streams, all carving the deep, winding canyons which have given this country its name.

The Canyon Lands terminate, approximately, at a third, intermittent barrier formed by the Paria Plateau, Black Mesa, and the Chuska Mountain mass. Southwest of this third barrier lies the great valley of the Little Colorado River and the adjacent House Rock Valley—a semidesert grassland, piñon pine, and juniper country which, in spite of its enormous area, contributes but a meager stream flow because of the sparse annual rainfall and snowfall. Winters are mild and summer temperatures about the same as in the Canyon Lands.

South and west of the Little Colorado River, the last great highland barrier extends in a vast curve

Figure 4.—Canyon Lands of southeastern Utah—looking over the junction of the Green and Colorado Rivers to the Henry Mountains from Dark Canyon Plateau.

across the Colorado River Basin from the southern boundary of Utah through Arizona to western New Mexico. This barrier is formed by the Grand Wash Cliffs, the Coconino and Kaibab Plateaus, the San Francisco group of volcanic peaks which rise above 12,000 feet, the long but narrow Mogollon Plateau averaging above 7,000 feet, and the 11,000-foot crests of the White Mountains. Heavy snowfall, long winters, and cool summers with afternoon thunderstorms characterize the climate of most of these highlands.

West and south of this last barrier lies the great southern desert of Nevada, Arizona, California, and Mexico. Rainfall is scanty and the summer season long and intensely hot. Winters are mild. Many low mountains rise from this desert. The most important of these ranges are the Hualpai, Harquahala, Santa Maria, Bradshaw, Pinal, Santa Catalina, Rincon, Galiuro, Pinaleno, Santa Rita, and Chiricahua Mountains. They comprise a series of cool islands rising out of the surrounding desert heat rather than a climatic or physiographic barrier.

The life zone map (Pl. 12, in pocket) summarizes graphically the natural features of the Colorado River Basin. It indicates the climates of the basin and their characteristic plants and animals. In view of the close relation between temperatures and altitudes, to be described later, the map also shows enough of the topography to furnish a rough three-dimensional presentation of the basin, the extent of the many great plateaus, the island-like distribution of many of the southern mountain ranges, and the deep penetration of the Rocky Mountains by numerous long, winding valleys.

The life zone map indicates the nature and distribution of the basin's various recreational regions. The Lower Sonoran Zone is principally a winter recreation region, where the desert scenery and sunshine are ideal for photography, swimming, camping, hiking, horseback riding, and motoring, and where some hunting and fishing may be enjoyed. The Upper Sonoran Zone, in valley and plains lands, provides recreational opportunities similar to those of the Lower Sonoran Zone, but is usable in summer when the latter region is too hot for comfort. The northern limit of the Upper Sonoran Zone is generally open sagebrush country not suitable for winter recreation.

Figure 5.—The great southern desert—Organ Pipe Cactus National Monument, Ariz.

The Transition Zone of the foothills and lower mountains probably attracts more vacationists than any other because it is the principal retreat of those seeking to escape from the summer heat of the lowlands. The location of this zone at the lower mountain levels usually renders it easily accessible at all seasons, while the coolness which accompanies its ample precipitation makes it the principal zone of winter sports. In the Colorado River Basin, water is most plentiful in the Transition Zone, so that it includes most of the best natural fishing areas, and for similar reasons the finest forests. With this abundance of vegetation are associated most of the big game animals, affording maximum opportunities for hunting and wildlife photography. In fact, nearly every form of outdoor recreation may be found in the Transition Zone and many kinds reach their highest development there.

The Boreal Zone is the high mountain recreational region. In the northern half of the basin it is visited nearly as frequently as the Transition Zone because it extends to fairly low levels. However, in the southern half of the basin it is, as a rule, sufficiently difficult to reach that only those who can appreciate its wilderness character are likely to penetrate it very deeply or permanently. High mountain recreational developments usually are restricted to the general vicinity of the relatively few roads that penetrate Boreal regions, and such developments are further restricted in their operations by the extreme shortness of the summer season. Camping, hiking, fishing, horseback riding, winter sports, photography, and the enjoyment of wildlife and rare flowers reach their culmination for many persons in this remote, and, to many, most beautiful and inspiring of all recreation regions.

LIFE ZONES

Because the basin embraces latitudes from Mexico almost to Yellowstone National Park, and altitudes ranging from 248 feet below sea level to 14,431 feet above sea level, all of the life zones of the United States are present except the Tropical Life Zone of southern Florida. These life zones are as follows:

Boreal Zone.—In detailed studies of small areas this often is subdivided into three zones—Alpine, Hudsonian, Canadian—but these finer distinctions are needless here. This zone is characterized by the cool, moist climate of Canada and the northern coniferous forest belt of the United States. Winter snows are heavy and long-lasting. Total annual precipitation is from 23 to 60 inches or more. On the other hand, at the lower levels of the Boreal Zone in the arid Upper Green River Valley of Wyoming, annual precipitation may be as low as 15 inches in some localities.[1] The annual mean temperatures are in the neighborhood of 45° to 27° F. or less. Narrow tongues of the Boreal Zone extend far south of the main area along various high mountain crests such as the Rockies. With the increase in average temperature toward the Mexican border, the tongues give way to a series of scattered islands as the zone becomes restricted to the tops of the loftiest peaks.

In the Colorado River Basin, the most reliable and conspicuous plant indicators of the Boreal Zone are the lodgepole pine, limber pine, whitebark pine, white pine, foxtail pine, white fir, alpine fir, Engelmann spruce, blue spruce, dwarf juniper, aspen, red elderberry, dogwood, and the blueberries. Extensive timber line grasslands and scattered high mountain meadows also occur in this zone.

Some of the more interesting or conspicuous animals and birds that characterize the Boreal Zone are the pine squirrel, marmot, cony, snowshoe rabbit, lynx, red fox, marten, wolverine, goshawk, three-toed woodpecker, Rocky Mountain jay or camp robber, clark crow, and crossbill.

Transition Zone.—The zone was given this name because it was considered to be essentially an area where the ranges of many northern (Boreal) and southern (Sonoran) plants and animals overlapped. Although this is to some extent true, the Transition Zone possesses a quite distinctive climate and a number of prominent and characteristic species of its own.

In Wyoming, Colorado, and northern Utah, where the Boreal Zone covers all the major mountain masses, the Transition Zone occupies the foothills and higher valleys. Farther south, however, where the Boreal Zone is restricted to projecting tongues and isolated high peaks, the Transition Zone occupies most of the mountain masses, and is

[1] Dr. John W. Scott, letter, 1946.

Figure 6.—Boreal Zone—Lake Brennan, Colo.

replaced in the valleys by a warmer climate. Winter snows are moderate. Total annual precipitation is from 17 to 26 inches, occasionally as much as 32 inches, and sometimes more.[2] Annual mean temperatures usually are between 40° and 50° F., except in a few Transition areas of extreme cold and aridity such as the Upper Green River Valley at Pinedale and Kendall, Wyo.[3]

Throughout a large part of the Colorado River Basin, this zone coincides very closely with the open, parklike ponderosa pine forests of the mountains and foothills, but north of the San Juan Mountains, Uncompahgre Plateau, and the Aquarius Plateau, the Transition Zone becomes a partially open region, characterized by sagebrush valleys and grassy slopes, often covered with Gambel oak and other chaparral shrubs. This reduction of forest growth may be due to the fact that precipitation in that region is relatively light even at the higher altitudes, while soil moisture and average relative humidity are further reduced by frequent high winds.[4] In this northern part of the basin the ponderosa pine gradually is replaced by Douglas-fir, but distribution of the latter within the zone often is restricted to steep slopes, shady areas, or the crests of plateaus above 7,000 feet, leaving the major part of the zone to the sagebrush and chaparral.

Other plant indicators are the narrow-leaved cottonwood, Utah oak, bur oak, bearberry, Rocky Mountain birch, Oregon or holly grape, elderberry, maple, locust, and alder. The sagebrush previously mentioned cannot be used as an exclusive indicator of the Transition Zone because it occurs even more extensively in the next warmer zone and sometimes enters the lower limits of the Boreal Zone. Since hardly any two kinds of plants, or animals, have precisely the same climatic requirements, the location of zone boundaries is based upon the presence of not one but a large number of the appropriate indicators. Obviously, therefore, the establishment of sharp lines of division between zones represents merely a compromise among various arbitrary decisions that it is necessary to make in order to draw up an intelligible small-scale map.

[2] 37.5 on summit of Mount Lemmon, in Arizona (Schwalen, 1942, p. 142 and map).

[3] Martin and Mattice, 1930, p. 12

[4] F. Martin, 1930, p. 2.

Figure 7.—Upper Sonoran Zone—Canyon Lands of southeastern Utah.

Animal indicators confined to, or particularly characteristic of, the Transition Zone include the tuft-eared squirrels, certain local races of wood rats and pocket gophers, and other small rodents, wild turkey, and band-tailed pigeon.

Upper Sonoran Zone.—This and the next zone take their names from the Province of Sonora in Mexico, from which they derive some of their plants and animals. Climatically, the Upper Sonoran Zone is considerably cooler than much of Sonora. It comprises most of the broad lower valley lands of the basin except in southern and western Arizona, southern Nevada, and adjacent California, where it gives way to a still warmer climate and becomes the principal life zone of the foothills, ex-

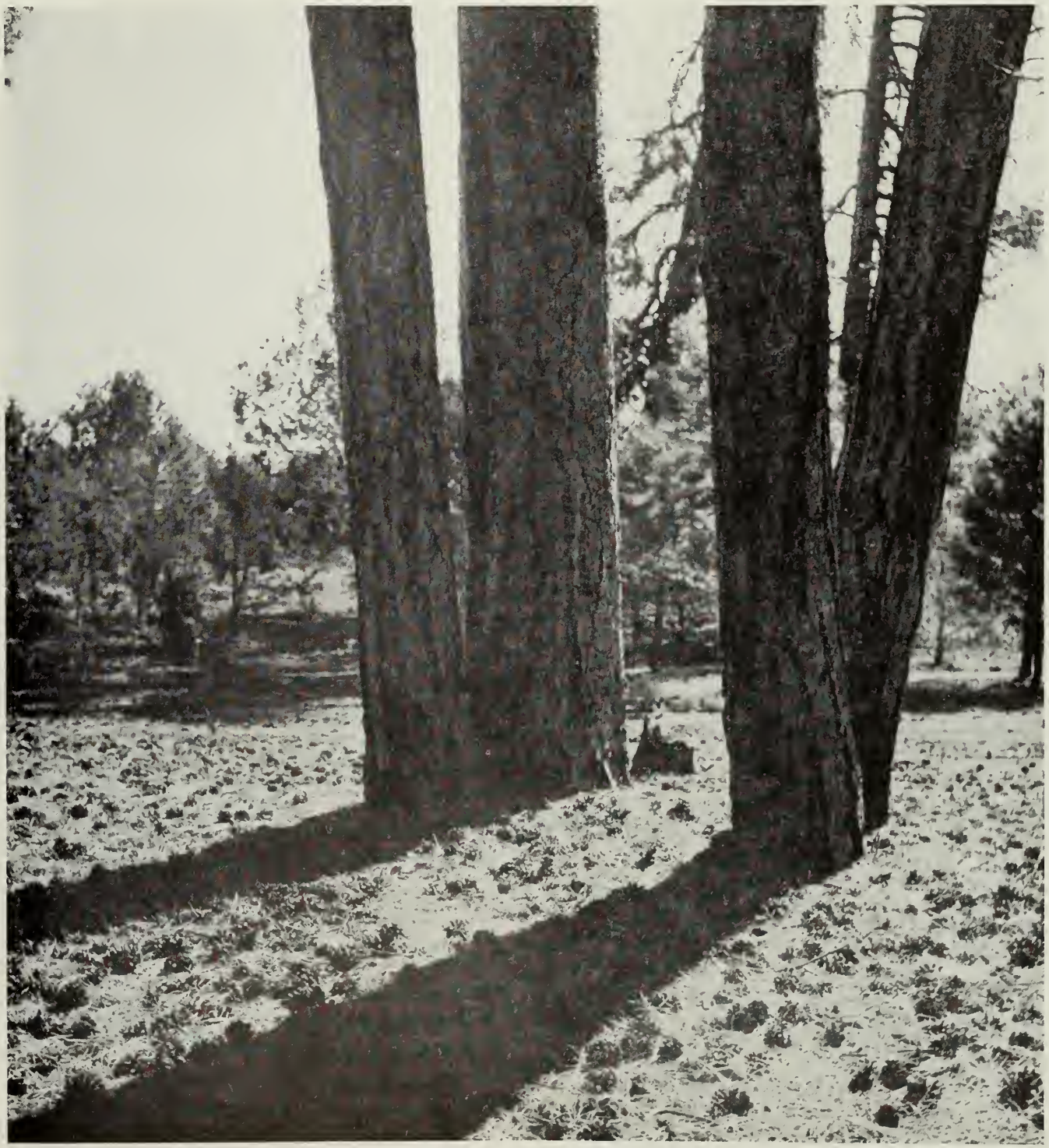

Figure 8.—Transition Zone—Shivwits Plateau.

tending even to the summits of the lower desert mountains. Snow is light or absent, and the summers are warm. Total annual rainfall usually is from 10 or 12 to 18 inches, occasionally more, and annual mean temperatures are between 50° and 65° F.

The Upper Sonoran Zone is typified by the seemingly endless foothill and mesa regions, sparsely covered with junipers (3 species) and piñon pines, that comprise vast areas in the Colorado River Basin. The zone is practically coextensive with these trees wherever they occur but is by no means restricted to such areas. It includes also extensive regions formerly covered with nutritious grasses where soil and moisture are too meager for piñons and junipers; also the alkali plains, sagebrush flats, and parched wastelands of the Upper Green River Valley and Red Desert in Wyoming, the sandstone barrens in the Canyon Lands of Utah, and the shortgrass and alkali plains of the Little Colorado River.

Some parts of the Upper Sonoran Zone that have a slightly greater rainfall and higher mean temperature than the piñon-juniper region support an extensive belt of scrub oaks.[5] Growing conditions seldom are favorable enough to permit these scrub oaks, which comprise several species, to become full-sized trees. Usually they are low, spreading shrubs that form dense thickets covering thousands of acres of foothill country. The Upper Sonoran oak brush is prevalent in the disconnected chain of foothills and low mountains south of and paralleling the Mogollon Plateau in Arizona, and is well exemplified in Kirkland Valley and the hills south of the town of Prescott. It also occurs, though apparently less extensively, in some comparable foothill areas of southeastern Utah and southwestern Colorado, such as the Abajo Mountains.[6]

Additional plant indicators are the sycamore, boxelder, greasewood, hackberry, cliffrose, silktassel, rabbitbrush, winterfat, and antelope brush. Mammal indicators include several species of small rodents, shrews, and bats which are not listed here because of the difficulty encountered by the average person in distinguishing these species from quite closely related animals inhabiting adjacent life zones. Such a list would be of practical use only to the technical worker, who can readily obtain such information elsewhere.

Bird indicators also are numerous, but, as in all of the life zones, only those are given this status that are known to *nest* in the zone in question. After nesting season, most of these birds spread into adjacent life zones, so that here again, a list of breeding birds would be of little help to any but the technical worker. The few birds that are listed as indicators elsewhere in this outline are believed to be year-round residents of the zone concerned. The piñon jay probably comes the closest of any bird to being a year-round resident of the Upper Sonoran Zone, but even this species wanders briefly into other regions.

Lower Sonoran Zone.—This, the last and lowest of the Colorado River Basin life zones, is the hot southern desert zone. It extends from Mexico northward into Arizona as far as the highland barrier formed by the Grand Wash Cliffs and the previously described chain of foothills and low mountains that parallel the Mogollon Plateau and White Mountains. It completely surrounds many of the southern desert mountains as an ocean surrounds an island, particularly in the southeastern part of the State, while other mountains of lesser height, including the many low ranges of southwestern Arizona, are completely submerged by it. This zone occupies the Salton Sea region (among other places) of California and extends long fingers into the lower valleys of southern New Mexico. It occupies the desert plains and valleys of southern Nevada and extends a dilute arm for a short distance into the adjacent Virgin River Valley of southwestern Utah. Another dilute extension of the zone threads its way up the Colorado River, deep beneath the surrounding land surface, between the sheer, heat-reflecting walls of the Grand Canyon. It extends briefly at the lower end of the Little Colorado River Valley in the vicinity of Cameron, and in the lower Paria and Wahweap Valleys above Lees Ferry.

Snow is practically absent, and annual precipitation averages from 1½ to 12 or 15 inches. In some

[5] Nichol, 1937, p. 183.

[6] Many ecologists separate the scrub oak belt from the piñon-juniper area, which more commonly denotes the Upper Sonoran Zone. Such a subdivision is entirely justifiable for local studies, but the climatic differences are relatively minor, and a large number of animal life zone indicators are common to both, so that for broad descriptive treatments of climate in such large areas as the Colorado River Basin, the old system of combining them into one zone is retained here for simplicity's sake.

parts of the zone there may be no rain at all for 2 or 3 years, but irregularly occurring cloudbursts help to raise the average figure. The summers are long and in many areas intensely hot, and annual mean temperatures are between 51° and 74° F.

The Lower Sonoran Zone is the zone of mesquites, many kinds of cacti, and the creosotebush. The mesquites are too dependent upon subsoil moisture to occur throughout this zone, while some kinds, though not all, of the cacti are sufficiently tolerant of cold to occur well beyond its limits. The creosotebush is the most conspicuous, widespread, and characteristic single plant of the Lower Sonoran Zone, and is almost coextensive with it except that it does not occur in the poorly drained alkaline soils of the desert sinks.

Other Lower Sonoran Zone plant indicators are the screwbean, catsclaw and other acacias, ocotillo, desertthorn, allthorn, paloverde, smoketree, tesota, bluethorn, varnish bush, arrowwood, century plants, and sotol.

Mammals used as indicators by ecologists include the round-tailed ground squirrels and cotton rats, as well as various other rodents whose close relatives occur in adjacent zones. Among birds, the white-winged dove, Arizona cardinal, and Arizona pyrrhuloxia are good indicators where they occur, but their range within the zone is not as wide as that of the mammals.

LIFE ZONES IN RELATION TO ALTITUDE

In general, the higher the altitude the cooler the air; roughly, the temperature decreases 3½° F. for each increase of 1,000 feet in elevation above sea level. Stated in another way, an increase of 1,000 feet in altitude is equivalent to a northward shift in latitude of approximately 200 miles. An easily remembered illustration is experienced by anyone who travels over the desert in summer by airplane. On taking off at approximately sea level from a desert airport that is sweltering under a temperature of, say, 110° F. in the shade, a few minutes' climb to 5,000 feet brings a reduction of temperature to 92° F., followed by a further drop to 74° F. if one continues through the upper layers of air to the 10,000-foot level. One can even fly over Death Valley during midsummer in complete comfort in a

Figure 9.—Lower Sonoran Zone.

818271°——50—3

plane at 11,000 feet, and no doubt this new form of recreational travel will become increasingly important in desert regions and elsewhere.

The lowering of temperature with increasing altitude helps to explain the permanent coolness of mountaintops, and why they constitute islands with a northern climate rising above the surrounding ocean of warmer air. On these island summits cling assemblages of cold-climate plants and animals that have been stranded there since the last Ice Age, when more than one-half of the continent was buried under a vast, unmelting crust of ice and snow. In southern regions these mountaintops usually are choice recreation areas.

LIFE ZONES AS MODIFIED BY DIRECTION OF SLOPE AND OTHER LOCAL INFLUENCES

Although latitude and altitude are the major factors influencing the climate of the Colorado River Basin, many interesting and striking modifications of climate by minor influences are visible even to the casual traveler and recreationist, and a knowledge of some of their causes heightens interest in the region.

Direction of slope.—South-facing mountainsides are exposed to the warming and drying effects of sunshine to a much greater degree than are north-facing slopes. On steep slopes, the difference often is so extreme that a given climate or life zone, say the Upper Sonoran oak brush, may extend on the south side all the way to the summit, at 7,500 feet, in spite of the low temperature of the surrounding air at this altitude. On the shady, moist, north side of this mountain, on the other hand, the Upper Sonoran Zone may give way near the base of the mountain, at 6,000 feet, to a cool forest of ponderosa pine. One may see just such a contrast on the opposite sides of innumerable hills, buttes, and low mountains throughout northern Arizona and New Mexico and southern Utah.

The warming effect on south-facing slopes is still further increased by the circumstance that an inclined surface facing the sun at a right angle may receive almost one and one-half times as much heat and light as a level surface. The inclined *north-facing* slopes on the other hand, receive *less* sunlight than a level surface.

Additional results of this difference are that snowbanks on north-facing slopes linger longer, and soils warm up and dry out more slowly or not at all. Spring flowers come later and birds may commence nesting 2 weeks later than their neighbors on the other side of the mountain. On many mountain peaks in the southern part of the basin, it is only on the shady north slopes that sufficient moisture remains throughout the dry season to permit the existence of a Boreal Zone fir forest. This situation occurs on Sitgreaves, Bill Williams, O'Leary, and the San Francisco Peaks, and in the Santa Catalina Mountains, as well as numerous other places in Arizona.[7] In general, mountain peaks intercept a greater precipitation than lowlands. The degree of interception is approximately proportional to the altitude of the peaks above the lowlands, the precipitation increasing about 1 inch per 160- to 200-foot rise.[8 9] In some places, however, the atmospheric currents often have been so robbed of their moisture by the time they reach the lee side of the mountains that the latter have a dry climate that is out of proportion to their altitude. Blacks Fork in the lee of the Wasatch Range is an example of this. Though at an elevation of 9,500 feet, it has an annual average precipitation of only 21.6 inches. Similarly, in Utah, Monticello receives much more winter and spring precipitation than La Sal at the same altitude, because the former is on the windward side of high mountains, whereas La Sal is on the lee side.[10]

Moisture.—In general it has been established that for an area such as the Colorado River Basin, the northward distribution (or on a mountain, the upward distribution) of plants is determined by the lowering temperatures, while the southward (or downward) distribution is limited by the progressive decrease of moisture.

In many parts of the basin there are striking il-

[7] Shreve, 1915, pp. 12, 33.

[8] Woodbury, 1941, p. 255.

[9] Precipitation does not increase with altitude at a regular rate in all regions. In southeastern Utah, for example, to take some extreme cases, it averages 1 inch for each 112 feet of rise between St. George and Andersons Ranch (near Leeds); 1 inch per 328 feet between Castle Dale and Hiawatha; 1 inch per 730 feet between Green River and Castle Dale; 1 inch per 403 feet between Green River and Watson; and 1 inch per 515 feet between Duchesne and Fruitland. Martin and Corbin, 1930, p. 3.

[10] Martin and Corbin, 1930, p. 3.

lustrations of the ability of northern zone plants of the higher mountain levels to survive in the lower zones, provided their moisture requirements are satisfied. Two or three miles southwest of Lyman's Reservoir, near St. Johns, Ariz., a small isolated cinder cone, grassy and otherwise devoid of trees, has on its shady north-facing slope a shallow steeply sloping ravine within the narrow confines of which there stands a slender file of ponderosa pine. Obviously a snowbank lingers in this shaded defile long after other snows are gone, thus providing moisture sufficient for the small colony, which is a mile or more from the main body of the forest and at a lower elevation. Similarly, countless mountain streams through the basin, long after descending from the cool highlands into the warm lowland valleys, are lined with pines and other mountain trees which, having been carried down as seeds, were able to establish themselves along the moist stream banks in the midst of an otherwise alien environment.

Spectacular examples of climate extensions downward into a lower zone may be seen in the Canyon Lands of Utah. There the streams, upon leaving the mountains, frequently vanish into narrow, shadowy gorges of great depth which wind erratically for miles below the rolling surface of the sandstone mesas, on their way to join the canyon of the Colorado. The Transition Zone pines, in following these streams down from the mountain slopes, likewise disappear beneath the surface of the desert, and may be glimpsed only from the brink of one of these gorges or from an airplane. This reversal of the usual altitude relationships is well illustrated in Indian Creek and Montezuma Creek Canyons at the base of the Abajo Mountains, and similar examples occur over great areas of the basin, as on the Black Mesa, and at the edge of the Defiance and Mogollon Plateaus in Arizona. Likewise, the outlet streams of Boulder, Fremont, and other large lakes at the foot of the Wind River Mountains, in the Upper Green River Valley of Wyoming, carry long tongues of Boreal Zone lodgepole pines and aspens down through the treeless, grassy Transition Zone.

Air currents.—Cold air tends to flow down canyons from the high peaks, especially at night, thus further promoting the downward migration of northern plants and animals along the stream banks.

On the other hand, rising currents of warm air, especially those which sweep over mountain slopes from adjacent desert lands, have a reverse effect and carry the climate of the lower levels to a much higher elevation than usual. The Colorado River Basin contains countless examples of this upward shifting of the lower zones adjacent to desert areas.

The Gila Mountains in southeastern Arizona exceed 6,000 feet and under other circumstances would be expected to have a Transition Zone pine forest at the summit. The heat of the San Simon Valley, however, carries the Upper Sonoran Zone to the summit of the range. A similar condition occurs, in varying degrees, in the Little San Bernardino Mountains north of the Salton Sea in California; in the Virgin Mountains of southern Nevada and northeastern Arizona; the Kaiparowits Plateau and San Rafael Swell in Utah; and in extensive foothill regions of the Green River Valley north of the town of Green River, Wyo.

Mountain masses.—The larger the mountain mass, the greater the area of cool surface, and the less the likelihood of its being affected by the warming influences of surrounding lowlands. The great frigid mass of the Rocky Mountains, together with such lofty spurs as the San Miguel and Elk Mountains, and the White River Plateau, is able to maintain a Transition Zone climate at lower altitudes than can the isolated Henry and Abajo Mountains in southwestern Utah.

A result of the proximity of mountain masses that is particularly noticeable in desert regions is the greater soil moisture at their bases derived from run-off.

> In the Colorado Desert, even in rainfall areas of 5 to 9 inches, many mountain barriers lifting up to 4,500 feet or more will knock out from 14 to 16 inches of rainfall per year . . . (In) the Kofas . . . while they form a mountain island only 4,200 feet high . . . there is an increased run-off deriving from about 14 inches of rainfall per year, and this moisture, and the consequent food and cover that it produces, supports (or did support before excessive hunting) a relatively abundant fauna of mule deer, sheep, quail and other forms of

small bird and animal life which would be largely absent from the area were it not for this.[11]

FISH LIFE IN RELATION TO LIFE ZONES

The distribution of fresh-water fish often is closely related to stream and lake temperatures, but because such temperatures may be greatly modified by local factors extraneous to the general climate, such as source and volume of stream flow, proportions of sunlight and shade, and the size and depth of lakes, fish have not been used as life-zone indicators. Nevertheless, in a broad study of an area as large and diversified as the Colorado River Basin, certain useful comparisons may be made between fish and other wildlife regarding the general effect of climate on distribution.

Boreal Zone.—The snow-fed, headwater streams and lakes of the high mountains are small, cold, and poorly supplied with fish food. The lack of food results from the prolonged low temperatures which permit a growing season of only a few weeks for aquatic plants and the various small organisms that feed on them and, in turn, are eaten by fish. The low temperatures retard the growth of fish directly by reducing the food supply, and indirectly by slowing up their metabolic rate. In addition to the adverse effects of low temperatures, there is a deficiency of organic matter and of plant nutrients in general in the higher parts of the Boreal Zone. Bare rocks and melting snows that produce water almost as pure as distilled water can provide only meager nourishment for the aquatic plants that comprise the basic link in the fish-food chain. Boreal Zone fish usually remain small no matter how long they live. Mortality during the long, rigorous winters runs as high as 60 percent.[12] Often, where artificially planted in high mountain lakes, they remain half-starved throughout the season and willingly take any lure, thereby affording some sport even though their size and the condition of their flesh may not always be up to par.

In addition to the native trout, various non-native trout have been planted in the basin, including the rainbow, brown, and eastern brook. For all of them the Boreal Zone comprises a submarginal habitat, and they do better in the warmer, more abundant waters of the Transition Zone.

Transition Zone.—The streams here are cold enough for trout requirements, but not so cold as to inhibit their growth. They traverse greater areas of fertile soil and pick up larger amounts of plant nutrients than Boreal Zone streams. Transition Zone streams, which drain extensive, moist mountain masses such as the Wind River, Uinta, and Rocky Mountains, may become large rivers occupying broad, fertile valleys and fringed by dense vegetation furnishing vital supplies of terrestrial insect food in addition to the abundant aquatic sources. The Transition Zone affords by far the finest natural trout fishing, and is exemplified by the Gunnison River in Colorado and its tributaries. Although trout are the most conspicuous and best-known fish of these mountain waters, a few minnows, suckers, and bullheads are present.[13]

Upper and Lower Sonoran Zones.—After the streams have traversed the long, sunny Transition Zone sagebrush valleys of Wyoming, Utah, and Colorado, or have dropped from the limited plateau and mountaintop Transition areas of the States to the south, the water has warmed up beyond the survival point for trout. This occurs at about 7,000 feet,[14] thereby coinciding approximately with the lower limit of the Transition Zone on land. Below this point the water not only becomes warmer, but also becomes more quiet and thereby loses the high oxygen content required by trout. It often picks up a yellow or chocolate-colored burden of silt which smothers food-producing aquatic plants, insects, and crustaceans, and buries spawning grounds. A few Upper Sonoran Zone streams which are fed by cold springs, such as Oak Creek and Bright Angel Creek in Arizona, are partial exceptions to this rule for a short distance, and provide fine trout fishing.

Trout soon disappear from the Upper Sonoran Zone, but a few more or less silt-tolerant species of warm-water fish are able to survive there. In the lower stretches of the Colorado and Green Rivers, the Colorado "white salmon" occurs in limited numbers. Actually it is an enormous minnow, occa-

[11] Nichol, A. A., 1945, letter.

[12] Needham, Moffett, and Slater, 1945, p. 19.

[13] Ellis, p. 123.

[14] Ellis, *op. cit.* p. 122.

Figure 10.—Trout fishing is excellent on the Colorado River below Hoover Dam.

Figure 11.—From Lipan Point on the South Rim of the Grand Canyon can be seen the Echo Cliffs and Navajo Mountain.

Figure 12.—Cliff Palace in Mesa Verde National Park, Colo., dates from 1066 to 1273 A. D.

Figure 13.—Petroglyphs in the Needles area southeast of the junction of the Green and Colorado Rivers.

sionally attaining a length of 3 feet, and a weight of 30 pounds. Small streams may harbor suckers, topminnows, and true minnows; the larger streams may contain, in addition, sunfishes, bonytails, perch, and catfishes, provided there is a zone of aquatic shore vegetation in which such fish spawn, and where their young can hide. Such plants also probably furnish some food. The turbid waters of the principal lowland rivers of the Colorado River Basin either fluctuate so greatly with the seasons, or have such a violent scouring action that such streamside and bottom vegetation is usually sparse or lacking.

Artificial reservoirs often completely reverse original stream conditions and may introduce the equivalent of an entirely different "life zone." This will be discussed more fully elsewhere and is mentioned here only to complete the zonal description of the basin. The construction of deep reservoirs like Lake Mead, which discharge large and fairly constant volumes of cold water from which the silt has settled out, has about the same effect as though a section of Transition Zone stream were substituted below the lake for a stretch of the previously barren, hot, and silt-laden river. In this cold stretch of water, trout have been introduced with great success, while in the clear waters of the lake itself, down stream from the silt deposition area, bass thrive, as well as such other introduced species as the bluegill and crappie, and the native warm-water fish previously mentioned. Carp also have been introduced into lower Colorado River waters but are considered undesirable.

RECREATIONAL RESOURCES

Recreational resources are all natural and cultural features which stimulate, encourage, or provide for the physical, mental, and cultural well-being of the individual. The mountains, with rushing sparkling streams shaded by tall pines in which birds sing; the call of a loon across a lonely lake; the overpowering spectacle of the Grand Canyon; Navajos and their sheep at a water hole in Monument Valley; cowboys riding fence or driving in cattle for the spring round-up; the cry of coyotes across the valley; trout and bass in Lake Mead luring the fishermen to the desert; Hoover Dam; the

Figure 14.—Bonita lava flow and Sunset Crater.

Figure 15.—San Xavier Mission near Tucson, Ariz., was built about 1790.

Figure 16.—Gunnison River above Gunnison, Colo.

Arizona Biltmore; the log cabin on Grand Mesa; the old mining towns such as Ouray, Silverton, Aspen, and Tombstone; the abandoned mine dumps where you may find some silver; the long purple shadows on the desert pavement; brilliant sunny days and starlit nights; the great open spaces and views without end; silence so complete the hum of a bee sounds like a distant airplane; Meteor Crater, that forceful reminder of the cosmic spaces, and Sunset Crater, equally forceful evidence of the earth's inner heat; Cliff Palace at Mesa Verde; Betatakin; pieces of broken pottery made centuries ago to hold corn; dinosaur tracks in red sandstone; petrified tree trunks; sea shells on a mountaintop; a startled deer leaping across a fragrant sagebrush flat—these and many more are the recreational resources of the Colorado River Basin. Nowhere else in the United States do the curious and fascinating land forms, evidences of the building up and wearing down of the earth's surface, stimulate more

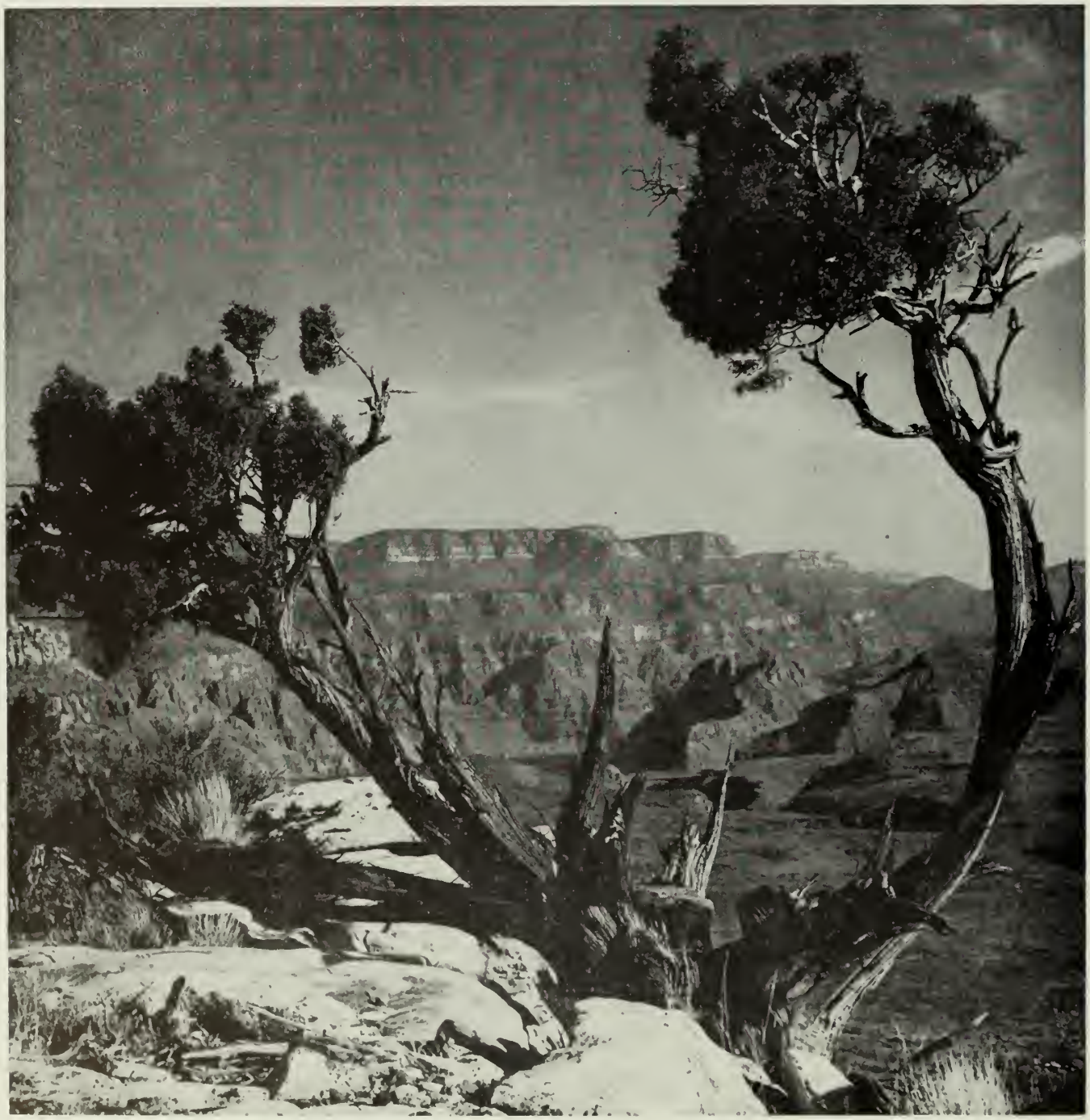

Figure 17.—The Grand Canyon at the mouth of Whitmore Wash.

interest in geology. Nowhere else are the evidences of prehistoric peoples so obvious and numerous. Nowhere else is there scenery so colorful.

Here is the world's greatest canyon, the largest natural bridge, the largest man-made lake (in volume), and the highest dam. Here too, one may enjoy much sunshine and find perfect climates for outdoor recreation the year around. Hunting, fishing, photography, snow sports, boating, swimming, horseback riding, camping, mountain climbing, exploration—the entire realm of outdoor recreational activities may be enjoyed. Five national parks and 33 national monuments have been established within the basin to preserve some of the most outstanding natural, scientific, and cultural features. Large sections have been included in national forests, wildlife refuges, and grazing districts, and vast areas have been set aside as Indian reservations. Much of the basin is in public ownership, but this is not surprising when one sees the country and knows that about half the basin has a population of less than 2 persons per square mile, and that the most densely populated county, Maricopa County, in which Phoenix, the largest city, is located, has a population of only 20.2 persons per square mile.

It is only natural in a region so endowed that recreation should become one of the major industries. Agriculture is restricted almost entirely to irrigated sections. Mining, lumbering, and the raising of cattle and sheep first attracted settlers to the basin, but the recreational features are now attracting many more, and as the various sections of the basin become better known and more accessible to the densely populated regions of the United States through improved highways and air transportation, catering to the recreationist should become a major industry. To foster this industry it must be recognized that recreational use of land may, in certain places, be the highest or best use of the land for the general welfare of the people in the basin and, in vast sections of the basin, should be on an equal basis with other uses, such as grazing or production of timber. The great stretches of open range, unobstructed by buildings, fences, transmission lines, and other signs of modern civilization, comprise one of the most important recreational features of the basin. As other sections of the United States become more and more highly developed, this one feature of the Colorado River country, if preserved, will have unusual appeal.

Figure 18.—Owachomo Bridge in Natural Bridges National Monument, Utah.

CHAPTER II

GEOLOGY

Provinces and subprovinces of the Colorado River drainage area, as recognized in this report, are based on physiographic character, on rock structure, and on the age of surface rocks. The value derived from using such subdivisions is chiefly that of ease in making descriptions of geologic features. Thus, elements of similar nature are considered together and contrasts are made apparent.

This portion of the report is prepared with a twofold objective: first, to present a general description of geology in the Colorado River drainage system and, second, to indicate specific features of unusual interest or unique character which should be permanently preserved and/or made accessible because of their educational or inspirational values. The general description of the area is essential to an understanding of the individual features which are discussed in more detail later. An appreciation of these features is essential in evaluating the recreational possibilities of the region or in planning its development.

GENERAL FEATURES AND RELATIONS OF DRAINAGE BASIN

In its continental relations, the area comprising the drainage basin of the Colorado is a feature of the great intermountain region outlined by the Rocky Mountains and the Sierra Nevada—an enormous expanse of relatively low land that might have been drained by a single river system. During Tertiary times this vast area was separated into two parts by the building of crinkled mountains in western Wyoming and uplifting masses of sedimentary rock to form the high plateaus of Utah. West of this common boundary is the Great Interior Basin, characterized by elaborately faulted and uptilted strata arranged as ridges between broad flats—a region of dwindling streams which never reach the sea. East of the division zone and extending to the crest of the Rocky Mountains lies the well-drained Colorado Basin, developed in dominantly flat-lying sedimentary rocks whose continuity has been interrupted by lava flows and igneous intrusions, and which in places have been bent upward into monoclinal folds or sliced into long earth blocks by faults. During a large part of Tertiary time the basin was the dumping ground for rock debris worn from its border lands. As a regional structural unit the Colorado drainage basin is a geosyncline—a downwarp formed at the time when its counterpart, the Rocky Mountains, was upraised.

An outstanding feature of the Colorado River Basin is the alinement and the peculiar local setting of the drainage channels. The original streams chose courses in accord with regional and local slopes and the relative hardness of the surface rocks. Some doubtless were through-flowing and others formed lakes, but nearly all of them eventually became parts of an integrated drainage system whose master stream, the Colorado, reached the sea. In the soft, uniformly textured Tertiary rocks that once covered most of the plateau country, the streams developed in the usual fashion, but as their channels were deepened, more resistant rocks in various attitudes were encountered. To escape these obstacles, some streams developed new roundabout courses, but many were so firmly established in deep trenches that readjustment was impossible, and as erosion of the adjacent lands proceeded their position became glaringly out of accord with the topography. Thus, with seeming disregard of regional features, the Green River crosses the Uinta Mountains, the Uinta Basin, and the Tavaputs Plateaus, and its tributaries pass through, instead of around, rock domes; the San Juan River meanders through Hogback Mountain and the Monument upwarp; the Paria River crosses the East Kaibab monocline; the Virgin River plunges through the Hurricane Cliffs, and farther on through the Bea-

verdam and Virgin Mountains; and the Colorado itself flows squarely across the Grand Hogback and the Waterpocket Fold and has cut a mile-deep trench across the Kaibab Plateau. Obviously, these streams, so strangely out of place in the present landscape, are superposed; they have inherited courses established on higher, less complex surfaces. They illustrate the superposed stream pattern characteristic of the entire Colorado drainage basin.

In developing their runways by down cutting, headward cutting, and the sluicing-out of rock waste, the Colorado and its scores of tributaries have removed from their drainage basin rocks with an average thickness of about 5,000 feet, and during this process have exposed all the major geologic formations. Along the Grand Canyon, where vigorous erosion has continued longest, rocks of Pre-Cambrian and Paleozoic age lie at the surface; northward across Utah, Mesozoic rocks predominate; and in southwestern Wyoming the floor of Tertiary limestones and shales is almost continuous.

In southern and western Arizona, below the great plateau region, the Colorado River and its tributaries drain an area totally different from that to the north. Rugged mountain ranges rise above broad, flat valleys like islands in the sea. The mountains contain rocks of many geologic ages and their structural histories are complex. Surrounding plains are in reality deep valleys that have been filled to thousands of feet with debris worn off the mountains within relatively recent geologic time. The present drainage follows the gentle surfaces of these valley floors between the ranges, flowing over sediments at low elevations.

The Colorado River drainage basin comprises areas of unlike physiographic and geologic history. For convenience of description they are listed as provinces, each of which is discussed as a separate unit. They are the Green River Basin, the Uinta Mountain Region, the Colorado Plateau (north and south portions), the eastern and western border lands, the Arizona mountain region, the Arizona volcanic areas, and the basin and range province. (Plate 3, in pocket.)

GREEN RIVER BASIN PROVINCE

In its broad relations, southwestern Wyoming and an adjacent narrow strip in northeastern Utah, together with an area of considerable size in northwestern Colorado, comprise a topographic depression of about 30,000 square miles, shown on modern maps as the Green River Basin or the western part of the Wyoming Basin. The basin is completely enclosed except for a deep trench in its south rim, through which the waters carried by the Green River and its large tributaries—Sandy Creek, Little Snake River, Yampa River, Vermillion Creek, La Barge Creek, and Blacks Fork—pass southward and finally reach the master stream—the Colorado. (Plate 3, in pocket.)

The general floor of this regional basin consists of flat stretches and broad slopes of gentle gradient trenched by relatively broad valleys and shallow canyons, but is roughened by ridges and elongated domes sufficiently high and resistant to erosion to outline somewhat poorly defined subordinate units. The Rock Springs Dome and the White Mountains separate the Great Divide Basin—4,200 square miles in extent—from the Bridger Basin, the latter extending along both sides of the Green River, from the foothills of the Wind River and Gros Ventre Mountains southward for 150 miles to the base of the Uinta Mountains. The lofty cuestalike Lany Rim and Cathedral Bluffs mark the boundary between the Bridger and Great Divide Basins and the Washakie Basin, and farther south the anticlinal Cherokee Ridge separates this structural depression from the much larger Yampa Basin.

Though its average altitude exceeds 6,500 feet, the Green River Basin is surrounded by mountains 10,000 to 12,000 feet high. At its northeastern border stands the massive Wind River Range. On its southwest side, the broadly exposed granite core of the range rises abruptly from the flat lands of Bridger Basin along a fault, and northeastward is flanked by the truncated edges of steeply inclined strata. The Wind River Range originated as an uplift in late Cretaceous time, during which thick, horizontal Paleozoic and Mesozoic strata were bent upward in elongated anticline. Then during a long period of erosion the up-arched strata were worn down to Pre-Cambrian rocks and the mass uplifted again and reexposed to erosion by the present-day powerful streams.

The southeastern border of the Green River Basin is defined by the Park Range, which essentially is a mass of ancient granite; the basal rock of

an anticlinal uplift that in Pre-Tertiary time was deeply mantled with sedimentary rocks. In consequence of erosion, a second uplift, and recent dissection by streams, the originally arched surface of the range has been worn down to a plateau of moderate relief, above which in places rise craggy, glaciated alpine ridges to heights exceeding 12,000 feet. The eastern border of the Green River Basin between the Park Range and the Wind River Mountains is poorly defined. For a distance of 125 miles the rocks characteristic of the crests of the high ranges along the Continental Divide occupy a huge structural sag, where they are covered by sediments of younger age. In the place of the usual topographic drainage divide, the margin of the basin is a sinuous line across featureless plains where the intermittent and ephemeral streams tributary to the Green River seem to be interlaced with those flowing eastward to join the Platte.

The western border of the Green River Basin is a belt of parallel mountain chains—the prominent Wyoming Range, Salt River Range, and Oyster Range—that rise 8,000 to 11,000 feet above the intermontane valleys, and southward decrease in height to less than 1,000 feet. Their component strata, chiefly sedimentary, are closely folded—much like those of the Appalachian Mountains—and are broken by faults of enormous dimensions. In the Bannock fault, 150 miles long, the rocks have been overthrust toward the east, possibly as much as 35 miles. At Aspen Ridge (Aspen Station, Union Pacific Railroad), an anticline is crossed by three long faults, in one of which (the Absaroka) the strata were raised more than 15,000 feet, bringing Jurassic rocks to the level of the Tertiary. These border ranges are famous as illustrations of geologic structure, and if made more accessible, doubtless would be visited each year by many students. (Plate 13, Sections 1 and 2, in pocket.)

The drainage pattern of the Green River Basin is peculiar; to an extent not duplicated elsewhere in the United States, the alinement of rivers and creeks is out of accord with the topography. Bitter Creek goes through, instead of around, the Rock Springs Dome, crosses a valley, and then plunges directly into the face of White Mountain. In the present topography an unobstructed course lies 1,000 feet below. Equally remarkable is the drainage of the Great Divide Basin, particularly the Red Desert, where the streams have no outlet. On a surface of flat land, ridges, and remnant mountains they terminate in alkaline lakes or die out on mud flats in the midst of brightly colored sand dunes—the all-year home of antelope and a winter grazing ground for sheep.

The interpretation of the anomalous stream pattern—its wholesale disregard of present day mountains—involves the assumption that the Pre-Tertiary rough floor of the Green River Basin—its highlands and lowlands alike—was completely buried by younger sediments and that the courses of streams established on the new-made surface have been maintained regardless of the structure and composition of the exhumed mountains encountered in down cutting. In geologic terms, the entire drainage system is superposed.

Within the Green River Basin most of the exposed rocks are sedimentary in origin and geologically very young. Lavas cap a few mesas and, at Leucite Hills, lavas, volcanic tuffs, and ash occupy about 750 square miles; in a few places Upper (?) Jurassic rocks are in sight; and Upper Cretaceous beds crop out in some valleys and inter-stream areas and are uptilted along folds and faults. But the basin is almost completely filled with Tertiary strata in nearly horizonal position. (Pl. 13, Secs. 1 and 2, in pocket.) The hard Cretaceous rocks form hogback ridges, while the poorly consolidated Tertiary strata erode into banded cliffs and picturesque castles, towers, "pulpits," and "witch rocks," in places into extensive badlands. From them have been obtained the fossil mammals, fish, birds, and plants exhibited in American and foreign museums.

Yampa River Valley.—The salient Yampa River Valley topographic and geologic features of the Green River Basin in Wyoming extend southward into northwestern Colorado where an area of about 2,000 square miles drained by the Yampa River, particularly its chief tributary, the Little Snake River, is surfaced with rocks of Tertiary age. This plainlike expanse, most of it north of the Yampa, is trenched by shallow streams, and its easily eroded soft rocks have been carved into attractive small-scale badland forms. Locally, the Tertiary beds are overlain by lavas or so far stripped away as to expose Cretaceous sandstones, igneous dikes, and vol-

canic necks. At the Elkhead Mountains, a lone mass of metamorphic and igneous rock that culminates in Hahns Peak (altitude 10,824 feet) interrupts the continuity of the flat-lying Tertiary beds. Near its mouth the Yampa has cut deeply into the steeply tilted rocks of the eastern Uinta Mountains, exposing the edges of Paleozoic and Mesozoic strata. The Yampa also transects Cross Mountain and, farther east, Juniper Mountain, which are short domelike masses that rise abruptly from the regionally flat surface. Like Douglas Mountain and Spring Mountain north of the river, these conspicuous landmarks are anticlines once arched over by Cretaceous rock but now so deeply eroded that the Cambrian and Pre-Cambrian core rock is exposed, and against it the Paleozoic and Mesozoic formations lie in orderly sequence. In shape and structure these isolated masses are so like the Uinta Mountains that they have been dubbed "Little Uintas."

Also suggestive of the Uinta structures is the remarkable Axial Basin—a valley formed by stripping away the crest of an anticline—which crosses the Yampa River and farther southeast merges with folds of the White River Plateau. The sequence of strata shows that the anticline is post-Eocene in age; the date of the second up-arching of the Uintas. South of Juniper Mountain, beyond the Axial Basin, the land rises to the anticlinal Danforth Hills, which stand 2,000 feet above the bordering lowland and outline the drainage divide between the Yampa and White Rivers. Here in the Cretaceous rocks, Goodsprings, Wilson, and Morgan Creeks, and Maudlin and Temple Gulches have cut deep channels across hogback, ridges, and the Collom syncline. From Juniper Mountain to Steamboat Springs, Colo., except near the mouth of Elkhead Creek, where Teritary rocks are exposed, the Yampa and its southern tributary flow on Cretaceous rocks, developing broad valleys and rounded hills in soft shales, and rugged landscapes of ridges, mesas, and "pagodas" in the most resistant sandstone. The many-branched Williams Creek, Trout Creek, and the Upper Yampa start abruptly at the Flat Tops—extensive sheets of basalt and andesite.

East of the latitude of Steamboat Springs, characteristic landscapes of the Yampa Basin entirely disappear. In the topography the plainlike surfaces developed on approximately horizontal beds are replaced by rugged mountains trenched by steeply inclined streamways and, as stratigraphic units, the dominant Tertiary formations are replaced by schists, gneisses, and granites. In other words, the southeastern edge of the Green River Basin—the northeastern edge of the Colorado River drainage basin—lies on the west slope of the Park Range and its features are those of the Rocky Mountains rather than of the plateau lands farther southwest.

If approach roads were available, the deep meandering canyon of the lower Yampa and a large part of the ruggedly carved landscape along its upper tributaries, now accessible only on foot or horseback, would add much to the recreational resources of northwestern Colorado (Plate 13, Section 5, in pocket.)

White River Valley.—In transporting White River Valley surface water and rock waste from northwestern Colorado to the Green River, the streams that drain the Yampa River Basin are assisted by those within the similar, but much smaller, White River Basin. Like the Yampa, the meandering White and its major tributaries have developed most of their channels in nearly horizontal Tertiary strata and have cut into Cretaceous and older rocks only where anticlines lie athwart their long-established route. In the soft Tertiary rocks, the streams have cut innumerable runways and thus have carved the surface into flat-topped ridges, mesas, and towers which are well displayed at Cathedral Bluffs, Gray Hills, Powell Park, and Douglas Peaks—features of the "Goblin City" mentioned by diarists of the second Powell Expedition. (Plate 13, Section 6, in pocket.)

UINTA MOUNTAIN PROVINCE

Uinta Range.—As a highland belt 25 to 40 miles wide with an average elevation exceeding 11,000 feet—2,000 to 6,000 feet above the peripheral lowlands—the Uinta Mountains are the dominating topographic feature of northeastern Utah between the Wasatch Mountains and the Green River. In some respects the Uinta Mountain region—the lofty Uinta Range and the Uinta Basin along its southern base—is unique. In contrast with the general north-south alinement of similar topographic features elsewhere in the Colorado drainage basin, in fact, within the United States, the mountain mass, its

Figure 19.—The Green River passes through Split Mountain, part of the Uinta upwarp.

bordering structural valleys and its principal fault lines trend east-west and, unlike that which characterizes the mountainous masses along the eastern edge of the Colorado Basin, the topography is in close accord with the structure. As a major feature of the regional landscape, the present Uinta Mountains differ little except in height from their ancestral forms; the crestline seems always to have been approximately the drainage divide and the bordering slopes to have retained their original position. The widely exposed core rock of the Uinta Mountains is the brick red, thickly bedded quartzite and sandstone of the Pre-Cambrian Uinta formation. On the flanks of this central mass, Paleozoic and Mesozoic formations in normal sequence are everywhere steeply tilted and, on the north and east sides of the mountain, broken by faults, some of great magnitude. (Plate 13, Sections 3 and 4, in pocket.)

The rocks of the Uintas contain a rich fossil fauna. The bones of dinosaurs are particularly abundant in the Jurassic Morrison formation at Dinosaur National Monument.

The major events in the geologic history of the Uintas include two periods of crustal movements, two of widespread denudation, and an epoch of glaciation. Soon after the close of the Cretaceous period the rocks of the region were pushed upward in the form of an elongated fold, thus bringing strata previously below sea level to altitudes exceeding 20,000 feet (Powell's estimate is 30,000 feet). This great up-arching was associated with downwarps paralleling its borders—on the north the Bridger Basin, on the south the Uinta Basin, and on the east the Yampa Basin. Then followed a period of erosion, an estimated 45,000,000 years, during which the range was greatly reduced in height. The bordering strata were truncated, and rock thousands of feet in thickness eroded from the highlands, the sediments being deposited in the adjacent basins, forming thick extensive deposits of sands and muds, now represented by the formations of early and middle Tertiary age. Before denudation ceased, the original lofty mountains had been worn down to a low-lying surface, probably of inconsiderable relief. In late Tertiary time, crustal upthrust was renewed, the remnant of the original arch was raised, and the edges of the flat-lying surrounding sediments were bent upward. There was thus introduced a second major cycle of erosion which has not yet come to an end. The new conditions have been favorable for roughening the surface of the mountain mass by cutting deep canyons and outlining peaks and ridges, especially along the borders. Twice during the glacial period the summit mountain surfaces were covered by ice. Thirty distinct glaciers, the smallest 1½ miles long and the largest 27½ miles long, extended down the highland valleys. Over an area exceeding 1,000 square miles only a few peaks and narrow divides escaped burial. The peculiar work done by these stationary ice caps and slowly moving ice streams is plainly recorded by striated rocks, cirques, U-shaped valleys, moraines, and glacial lakes—about 400 of them large enough to be shown on maps.

Most of the streams in the Uinta region are in accord with the topography, and also generally with the structure. They occupy synclinal troughs or descend the flanks of anticlines, and locally follow courses determined by the relative hardness and attitude of the rocks encountered. In other words, they are consequent or subsequent streams. A conspicuous exception to the normal arrangement is the Green which, after flowing southward for 150 miles over soft flat-lying rocks, abruptly turns east, crosses a great fault, meanders through the hard, steeply upturned rocks along the flanks of the Uintas, and passes entirely through the range in spectacular canyons. To account for this abnormal course involves the supposition, based on a study of the regional geology, that the ancestral Green River was established on a surface that lay far above its present canyon walls at a time when the eastern end of the Uintas was buried beneath strata of late Tertiary age. In consequence of readjusted alinement caused by the growth of its tributaries and by local tilting and faulting, the stream became so well established that it maintained its course, cutting through the soft rocks and on into the complex hard rocks—its present floor. Like many rivers in surrounding regions, the Green through the Uintas is superposed; its course has been inherited.

Uinta Basin.—Among the physiographic features of outstanding interest in northeastern Utah and northwestern Colorado, the Uinta Mountains are matched by the Uinta Basin which covers an area of about 8,000 square miles in Utah and 7,000 square miles in Colorado drained by the Green

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River and its large tributaries, the Duchesne, Uinta, Yampa, and White Rivers. From the Wasatch Mountains the basin extends eastward for about 170 miles to the White River Plateau, as a border belt for the Uinta Range and the Axial Basin anticline. Southward from the base of Uinta uplift it extends to the crest of the Book and Roan Cliffs 40 to 120 miles distant. Within this large area a few remnants of an ancient erosion surface are exposed, but generally the older rocks lie beneath thick deposits of Tertiary age exposed to view only in the deep canyons. These Tertiary rocks, 500 to 12,000 feet thick, floor not only the Uinta Basin but also the lands east and north of the Uinta Mountains. (Plate 13, Section 3, in pocket.)

The Uinta Basin is both a topographic and structural depression. In generalized north-south profile across its central part, the surface descends from 7,000 feet at the base of the Uintas to about 5,000 feet (along Green River, 4,000 feet), then ascends to altitudes of 8,000 to 9,000 feet. This topographic expression is largely in accord with the attitude of the underlying sedimentary rocks. In structure the basin is a long syncline; from its axis northward, the strata bend upward to the base of the Uintas and southward up the back slopes of the Tavaputs Plateaus.

The Uinta Basin is a profitable agricultural section, a potential oil field, and the site of the largest and oldest Indian reservation in Utah. It is a famous source of fossils, and derives additional geologic interest from its scattered outcrop of solid hydrocarbons, which include rare types, some of them unique and little understood—uintaite, native asphalt, ozocerite (mineral wax), wurtzilite, tabbyite, and bituminous sandstone. Especially peculiar are the deposits of commercially valuable gilsonite, which on both sides of the Green River fill deep vertical cracks 1 to 8 feet wide and 3 to 8 miles long, and appear at the surfaces as conspicuous black streaks.

COLORADO PLATEAU PROVINCE

Outline of geologic history.—The geologic history of the Colorado Plateau Province, now in vigorous process of destruction, is recorded in the composition, the sequence of deposition, fossil content, and geographic position of its constituent rocks. In broad outline it is the story of enormous masses of sedimentary rock raised high above sea level and dissected by the Colorado River and its many tributaries. Thus, in strong contrast with adjacent regions, its history is fairly simple and easy to read. In it six major events are recorded.

1. During Paleozoic and Mesozoic times—periods aggregating as much as 490,000,000 years—sandstone, limestone, and shale were deposited alternately on the ocean bed and on land, and progressively sunk, thus leaving each set of beds periodically not far above sea level.

2. Near the close of the Cretaceous era, approximately 60,000,000 years ago, the entire plateau country was uplifted. For the region as a whole, the raising of this enormous mass was accomplished without greatly modifying the original, almost horizontal attitude of its constituent strata. In places, however, the beds were warped into broad synclines, anticlines, and domes, and locally were folded into long narrow monoclines, conspicuously represented by the San Rafael Swell, the Kaibab Plateau, the Waterpocket Fold, and the Comb monocline.

3. Following this general uplift both the flat-lying rocks and the folded rocks were so completely worn down by streams that the surface again became substantially level.

4. On the surface produced by post-Cretaceous erosion, great thicknesses of Tertiary rocks were deposited over most of the plateau province, and upon them a master stream and subordinate streams were developed—the ancestral drainage system of the Colorado River.

5. After a large part of the Tertiary sediments and some of the lavas had been laid down the plateau country was again uplifted—substantially to its present height—and in places broken by faults. In consequence of the uplift, the gradients of drainage channels were greatly steepened; the streams became powerful agents of erosion.

6. During the past 20,000,000 years, substantially the present plateau landscape of canyons, cliffs, plateaus, mesas, terraces, and the amazing variety of minor land forms has been modeled, chiefly by stream erosion.

Regional features of northern portion.—The central part of the Colorado drainage basin is

Figure 20.—The Great White Throne. The Navajo sandstone in Zion National Park, Utah, is 2,280 feet thick.

unique in geologic history, topographic form, and scenic grandeur. Within it are displayed the oldest and youngest rocks exposed on the North American Continent, and the major subdivisions of the geologic time scale are represented in orderly succession. It is a vast expanse of plateaus, terraces, mesas, and cliffs that seem to have an unlimited range in form, size, and color.

Over an area of about 130,000 square miles in Utah, southwestern Colorado, northwestern New Mexico, and northern Arizona, plateaus that rise 5,000 to more than 10,000 feet above sea level are so numerous and prominent that the region well merits the various applied names—the Colorado Plateau province, the plateau province, the Colorado plateaus, or, considered as an areal unit distinct from surrounding regions, the Colorado Plateau. Outstanding features are the widespread Triassic, Jurassic, and Cretaceous strata in approximately horizontal position, the gigantic cliffs and the multitude of canyons that carry the perennial, intermittent, and ephemeral run-off. The sedimentary strata that lie above the meagerly exposed Paleozoic rock extend hundreds of miles with little change in character. They include series of shales 1,400 to 2,200 feet thick, of limestones 1,000 to 1,500 feet thick, of volcanic tuff 6,000 feet thick, and many single beds of sandstone 200 to 1,500 feet thick. In the walls of Zion Canyon the remarkable Navajo sandstone measures 2,280 feet—the thickest unit sedimentary bed so far known. In succession above the strongly predominant sedimentary rock extensive sheets of lava characterize the landscape in widely scattered areas. The edges of both these sedimentary and igneous beds are fully exposed in vertical, unscalable cliffs of seemingly interminable length that advance in headlands and retreat in bays, tower above the adjacent lower lands, and from their crests extend backwards to the bases of similar escarpments. Substantially the rocks in each of the great cliffs are of different geological age and are marked by distinctive colors—Lower Triassic, brown and light red; Upper Triassic, vermilion or brilliantly variegated; Jurassic, uniformly white or red, or regularly banded; Cretaceous, gray; Tertiary, pink, extending up and into white; and, the Tertiary and Recent capping lavas, black.

The major features of the plateau topography are so consistent that in distant views the long stretches of even skyline give an impression of extensive flat surfaces that terminate in lines of cliffs. The plateau country in reality is intricately dissected and closer inspection reveals a ruggedness possessed by few if any other regions. Over large areas the canyons are so narrow, so deep, and so thickly interlaced that the region seems made up of gorges, cliffs, and mesas and platforms, intimately associated with a marvelous variety of minor erosion forms. Some of the topographic features are developed on a scale that in other regions would justify the term "mountains." However, the plateau is essentially devoid of high peaks and narrow, serrate ridges. Like a deeply engraved intaglio, its departures from the regional surface are downward rather than upward.

For making a land of canyons, the physiographic conditions in the plateau province are especially favorable. The region lies at high altitudes; its climate is generally arid; its major rock strata are thick, resistant, and lie nearly flat; its longer streams receive abundant water from the adjacent humid Rocky Mountains and are at the stage in their life history where their ability to grind up rock and to transport the resulting debris is greatest. Consequently, innumerable deep, narrow trenches are cut into strata that otherwise remain intact, and the great beds of sandstone and limestone terminate in vertical walls. In striking contrast to the wide open valleys, the graceful slopes, and the rounded hills of most other regions, the topography of the plateau lands is abruptly angular, even in minor details.

Though the Colorado Plateau is generally floored with horizontal or slightly inclined sedimentary strata, its surface has been roughened in places by folding, faulting, the building of volcanoes, and the intrusion of igneous rocks—geologic activities that have modified the otherwise normal drainage pattern and the orderly development of erosion features. Of the folds, many are merely "rock wrinkles" of slight importance, but the larger upwarps and downwarps have produced elongated domes 90 to 150 miles long and 40 to 75 miles wide that in the present topography stand 1,000 to more than 3,000 feet above the adjacent land. Particularly conspicuous are the mountainous upwarps that brought into existence the isolated Uncompahgre Plateau, the San Rafael Swell, the Kaibab Plateau, and the Waterpocket Fold, the Defiance upwarp, and the Escalante anticline. Most of these folds are steeper

Figure 21.—The Colorado Plateau. Like a deeply engraved intaglio, its departures from the regional surface are downward rather than upward. *(Air photo)*

Figure 22.—Grand Gulch in the Canyon Lands of southeastern Utah. *(Air photo)*

Figure 23.—East side of the Kaibab Plateau upwarp. *(Air photo)*

Figure 24.—Navajo Mountain.

on their east sides where, in consequence of erosion, the strata that once overarched them are represented by remnant beds steeply inclined along their flanks. Few features in the plateau are more conspicuous than the upturned strata in the high, rugged hogbacks that characterize the Waterpocket, Comb, Echo, and East Kaibab monoclines. The larger folds, perhaps all the ridge-making folds, in the plateau country are the result of compressive forces directed horizontally from the east and confined to the sedimentary strata. Another type of upwarp in which the strata were raised by the intrusion of igneous rocks—laccoliths—is also exceptionally well represented. The lofty Navajo, Henry, Abajo, La Sal, Ute, and Carrizo Mountains, and similar structures in the Rico and La Plata Mountains, are essentially igneous masses that once were completely overlain by sedimentary rocks. In all of them except Navajo Mountain, which retains its cover, erosion has exposed the igneous cores. Similar to the laccolithic mountains in manner of formation are the peculiar faulted domes in the vicinity of the La Sal Mountains, where the strata have been deformed by the intrusion and expansion of masses of salt and gypsum.

In the southwestern part of the plateau province, where conspicuous folds are rare, the strata have been deformed by faults so large in dimensions as to completely remodel the landscape. They have sliced the region into enormous earth blocks, realined streams, and formed cliffs comparable in height and length to the towering escarpments developed by erosion. In roughly parallel position the Paunsaugunt, Sevier, and Hurricane faults, each nearly 200 miles in length, and the shorter Grand Wash fault, extend from south central Utah into Arizona and southward across the Colorado River. Along the east side of these fractures the stratigraphic formations have been raised a few hundred to as much as 7,000 feet above their counterparts on the west. The effects of faulting are typically expressed in the Zion National Monument, where the sharply defined Hurricane Cliffs, produced by the Hurricane fault, separates the flat-lying cultivated plain about New Harmony and Kanarraville from the uninhabitable Kolob Plateau, which stands more than 3,000 feet higher.

The remarkable unevenness of the regional surface produced by great faults has been intensified by the building of volcanoes and the outpouring of lavas during Tertiary and Recent times. Above the general surface of the Uinkaret Plateau in the southern portion of the province more than 150 ash and cinder cones rise to heights of 50 to 500 feet, and the tabular masses of lava that cap Trumbull, Logan, and Emma Mountains rise to heights of 1,000 to 2,000 feet. Similar igneous prominences characterize the adjoining Shivwits Plateau, and cones with attendant lava flows are conspicuous features of the St. George Basin, the Little Creek and the Kolob Terraces, and the valleys of Kanab and Johnson Creeks. Many craters are of such recent origin as to have retained their original features; others are worn to stumps or volcanic necks that, particularly in the Navajo country, rise sheer from the surface as towers of black rock. Likewise, some of the lava fields have been little changed, but others have been cut into fragments and, in the existing topography, are represented by the basaltic cap rock of many mesas and ridges and the thick sheets of andesitic lavas that cover Pine Valley Mountain, the Aquarius Plateau, and Grand Mesa.

Considered as a whole, the land forms that characterize the Colorado Plateau comprise a single physiographic province readily distinguishable from other parts of the North American Continent. However, the component plateaus vary so much in origin, altitude, degree of isolation, and amount of dissection that in geological literature they are classified by groups or sections. Certain areas of special scenic interest have been further segregated as national parks and national monuments.

Plateaus adjoining the Colorado River.—On both sides of the Colorado River from Lake Mead to Grand Junction, Colo., and for many miles along the tributary Green, San Juan, and Little Colorado Rivers, plateau topography is dominant. In the Grand Canyon section the Shivwits, Uinkaret, Kanab, Kaibab, and Coconino Plateaus terminate at the rim of the world's most spectacular gorge. In corresponding positions along Glen Canyon lie the moderately elevated Glen Canyon platform, the Paria, Rainbow, and Grand Gulch Plateaus, and the Kaiparowits Plateau which stands nearly 4,000 feet above the river at its base. The trenchlike Cataract Canyon separates Dark Canyon Plateau from the equally lofty Standing Rock Plateau

drained by the Dirty Devil and San Rafael Rivers. Farther upstream the Colorado River is bordered on the north by the Roan Plateau and on the south by the Uncompahgre Plateau and Grand Mesa. In valleys tributary to the Colorado River, plateau topography persists. In Green River Valley, East Tavaputs and West Tavaputs Plateaus, parts of an otherwise continuous highland, are separated only by the profound Gray Canyon; in the San Juan Valley, Grand Gulch and Chaco Plateaus, and the plateau-like Mesa Verde are prominent features; and above the floor of the Little Colorado River, continued as the Rio Puerco, stands the Moenkopi, Manuelito, and Dutton Plateaus. In topographic expression these extensive river-border platforms, which lie at relatively low altitudes, are similar and all are remnants of high-lying lands but, in consequence of crustal deformation and varying stages of erosion, they display rocks of different ages and in somewhat different attitudes. Thus the eastward tilted Shivwits, Uinkaret, and Kanab Plateaus are outlined by faults, and the Kaibab Plateau is a sequence of bowed strata bordered by monoclines. As these four plateaus occupy the area of greatest uplift, and consequently of unusually vigorous erosion, they have been worn down the most—to rocks of Permian age that farther north in the plateau country are exposed only in canyons. The adjacent East Kaibab monocline and, a short distance beyond, the Echo monocline, have so lowered the strata that along Glen Canyon, rocks younger than the Triassic are buried. In fact, throughout the Colorado drainage basin the rocks in most of the plateaus are of Triassic, Jurassic, Cretaceous, or Tertiary age.

The Uncompahgre Plateau, 20 to 30 miles wide and nearly 100 miles long, with summit altitude of 9,000 to 10,000 feet, is a flat-topped anticline in which the core of Pre-Cambrian granite is largely covered by Triassic and Jurassic rocks, which are magnificently displayed in Colorado National Monument. In forming the plateau, the strata of Paleozoic age were stripped away from a former highland mass before younger sediments were deposited. Throughout its life the Uncompahgre seems to have determined the local drainage pattern. On approaching it, streams from the Rocky Mountains and the northern San Juan Mountains are deflected; they follow the edge of the upwarped highland. Even the powerful Colorado, which once made its way through the barrier, has chosen an easier course—a great curve around its north end. Its abandoned runway through the deep, narrow Unaweap Canyon, 53 miles in length, is now an automobile highway. It seems strange that this outstanding illustration of stream adjustment has received so little attention.

Grand Mesa, "the world's largest flat-topped mountain," is an isolated outlier of the Roan Plateau, 50 miles distant across the Colorado. In it the Tertiary and older rocks are preserved by a thick cap of basalt. Its glaciated lake-dotted surface covers an area of 900 square miles at an altitude of 10,300 feet—5,000 feet above the surrounding lowlands. North of it stands the smaller Battlement Mesa—similar in form and geologic history.

Mesa Verde, 250 square miles in area, is a portion of a widespread highland, in essence a promontory extending from the San Juan Mountains, from which it is separated by the broad valleys of the Mancos and Upper Dolores Rivers. In distant view, its surface, at an altitude of 8,000 feet, appears to be smooth and continuous and, in conformity with the dip of the strata, to slope southwestward. In reality the mesa is ragged. Except along its northern edge, it is so elaborately dissected by scores of south-flowing, box-headed canyons and gulches that the interstream spaces are reduced to narrow strips. The whole frayed highland has been likened to a "worm-eaten log." The mesa is surfaced with resistant sandstone about 1,000 feet thick (the Mesa Verde group) and underlain by the easily eroded Mancos shale, 1,800 to 2,000 feet thick, thus providing conditions favorable for the rapid making of great cliffs at the edge of the strata while their surfaces were but slightly abraded. The northern face of the mesa is an escarpment 1,500 to 2,000 feet high. In sequence of geologic events, a regional uplift permitted vigorous erosion of the ancient highlands; the more exposed and the softer rocks were stripped down to the massive sandstones. In late Tertiary times the mean surface was doubtless coextensive with the peneplained surface of the southwestern San Juan and adjacent areas in the plateau province. Renewed uplift and erosion brought the structure to its present form.

The high plateaus of Utah.—Of the 10 great plateaus that dominate the topography of south

central Utah, the Pavant, Tushar, and Sevier are drained by westward-flowing streams; the Kaiparowits is the source of streams that go directly to the Colorado River; and the Wasatch, Fish Lake, Awapa, Aquarius, Paunsaugunt, and Markagunt Plateaus, and Pine Valley Mountains contribute water to the Colorado River and at the same time to the Great Basin. The plateaus that face the Colorado River are huge rock masses; nearly level platforms 25 to more than 500 square miles in area and bordered by terraced escarpments 4,000 to 5,000 feet high. From heights of 10,000 to 11,000 feet they overlook the lower series of plateaus along the Colorado River. Though the plateaus are now individual topographic units, it is believed that they once formed a continuous surface and that their present detachment is the result of faulting that has broken their once continuous surface into longitudinal, tilted earth blocks. The Paunsaugunt fault separates the Aquarius from the Paunsaugunt Plateau; the Sevier fault, the Paunsaugunt from the Markagunt; and the Hurricane fault, the Markagunt from the plateau-like Pine Valley Mountains. These long faults deformed all the sedimentary rocks and also the sheets of lava that overlaid them, some of them nearly 3,000 feet thick. This large-scale faulting accompanied by regional uplift introduced the long cycle of erosion still in progress. The Triassic, Jurassic, Cretaceous, and Tertiary rocks that form the stream-scoured fronts of the plateaus are but remnants. Corresponding formations appear south and east of Glen Canyon and doubtless once extended to the foothills of the Rocky Mountains. North of Grand Canyon, Triassic strata have been stripped back 30 to 80 miles, and the rocks of younger age still farther. To an extent not equalled elsewhere, the major erosion has been accomplished by wearing back the faces of cliffs rather than by abrasion and dissection of the plateau tops; erosion is directed against, rather than upon, the exposed strata. Because the individual rock layers differ in thickness and hardness, the protruding edges retreat at different rates, thus developing a zigzag vertical profile in which the resistant rocks appear as escarpments and the softer rocks as flats or gentle slopes. In other words, the plateau fronts are neither continuous nor broken curves: they are successive terraces that follow the contour for nearly 200 miles, and in distant view suggest a stairway whose ascending risers are the Chocolate Cliffs, Vermilion Cliffs, White Cliffs, and Pink Cliffs.

The high plateaus of Utah comprise a landscape famous alike for its esthetic appeal and its geological interest. Their crenelated skyline rims, their elaborately carved frontal escarpments, the canyon walls decorated with arches, bridges, and caves, and the picturesque towers and terraces in their foothill belts—all brightly colored—well merit the term "marvelous." Naturally, the unique landscape has attracted the attention of poets, prose writers, and artists, and its features have been reproduced in countless photographs in color. Each year thousands of persons go to Zion and Bryce Canyon National Parks and Cedar Breaks National Monument to view the spectacular scenery. To the scientist, the region is the most comprehensive textbook on Mesozoic history and on processes involved in erosion. Fortunately, the significant features of structure, stratigraphy, and volcanism are fully exposed, and the fascinating story of geological events needs no profound study for interpretation. Few places in the world afford better opportunity to realize the power and persistence of the forces that have shaped the surface of the earth, for though displayed on an enormous scale the rock units show a certain simplicity of mass composition, form, and arrangement that makes their relations clear.

Navajo Country.—The Navajo country, about 25,000 square miles in area, extends from the Little Colorado River eastward across Arizona into New Mexico and from the Rio Puerco northward to the San Juan and Colorado Rivers. Within this large area the landscapes are notably diversified. At its center lies the extensive, little-dissected Black Mesa, from which most of the major drainage passes southward through canyons in the high bordering cliffs and continues across relatively flat lowlands as shallow washes 40 to 60 miles long. East of Black Mesa the dominant topographic features are the up-arched Defiance Plateau and the lofty, narrow, cliff-walled Chuska Mountains, and the isolated Carrizo Mountains, which rise abruptly above the surrounding lowlands. The western part of the Navajo country adjoining the famous Painted Desert is substantially the surface of a chain of low-lying plateaus deeply trenched by the Moenkopi

and Navajo Creeks. At the north, overlooking the San Juan and Colorado Rivers, are the Tsegi Mesas —enormous blocks of red sandstone separated by profound canyons—and west of them is the conspicuous Navajo Mountain, whose dome-like summit (altitude 10,416 feet), 7,000 feet above the floor of Glen Canyon, is the highest land within an area of many thousand square miles.

There seems reason to believe that the prominent, detached high-lying sedimentary rocks in the Navajo country are remnants of once widely extensive formations that owe their positions to a regional uplift near the close of the Cretaceous period and that, during Tertiary and Recent times, the landscapes of pre-Tertiary times have been completely remodeled, chiefly by stream erosion. From a former general surface that stood perhaps 9,000 feet above sea level, the region has been worn down to an average altitude of about 5,000 feet, parts of it to less than 4,000 feet, and in consequence nearly all the Tertiary, most of the Cretaceous, large parts of the Jurassic, and some of the Triassic and Permian strata have been swept away. The volcanoes have been reduced to stumps, the lava flows to their feeding dikes, and deep-seated folds have been uncovered. Coincident with the removal of enormous masses of sedimentary and igneous rock, differential erosion has produced prominent topographic inequalities; flat surfaces that end abruptly at the base of terraced escarpments; mesas that rise at various stratigraphic levels above plateau surfaces, and streams that follow roundabout courses, in and out of canyons, across folds and hogbacks, with seeming disregard for rock composition, structure or regional slopes. Continuous vigorous erosion has exposed complete sections of the Permian, Triassic, Jurassic, and Cretaceous rocks and partial sections of the Tertiary and Carboniferous. In fact, the type sections for many Permian and Mesozoic formations are in the Navajo country.

Furthermore, in consequence of regional denudation, igneous rocks, particularly intrusives, are unusually well displayed — seemingly extraneous features of a landscape modeled almost wholly in

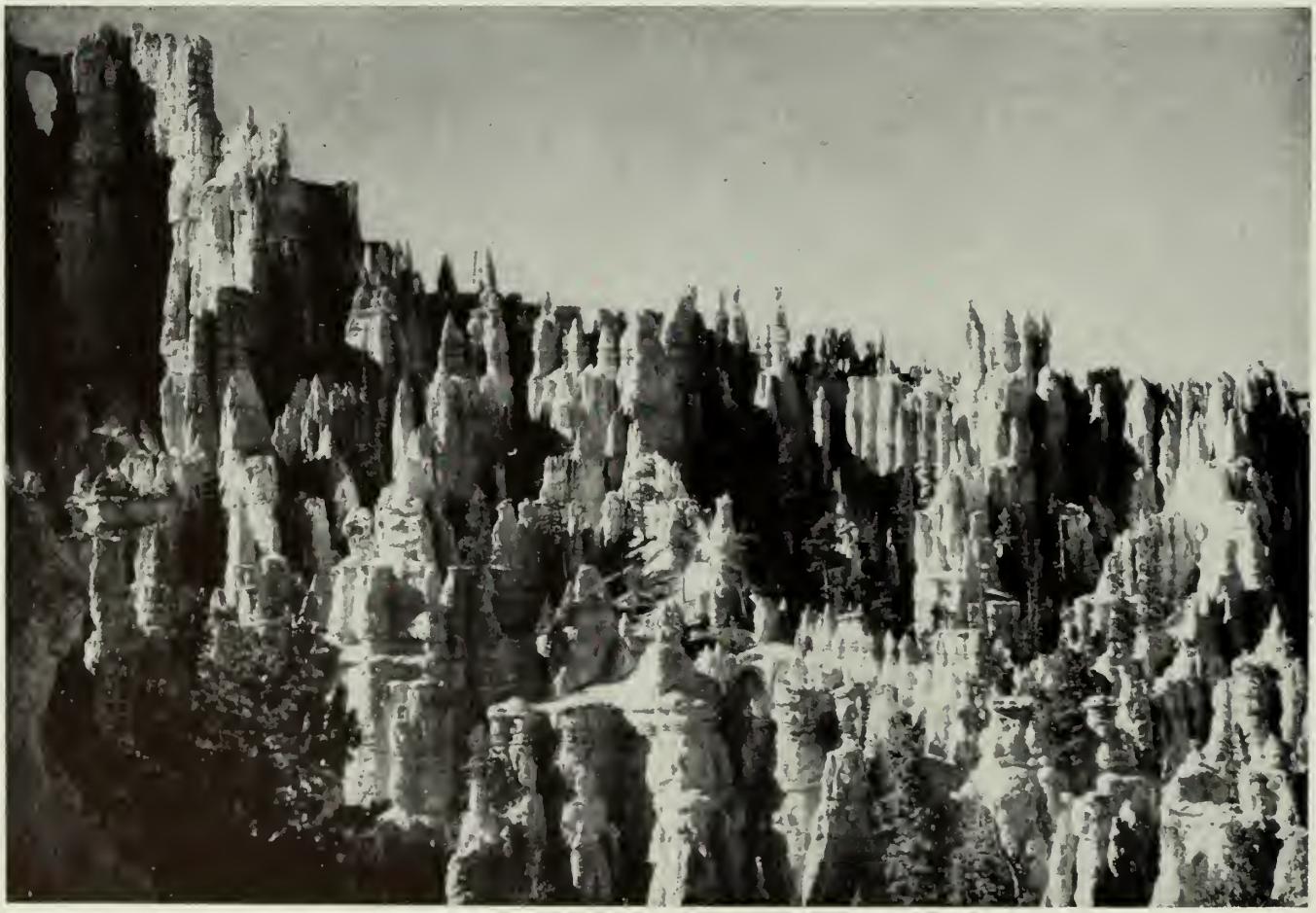

Figure 25.—Elaborately carved frontal escarpment, Bryce Canyon National Park, Utah.

sandstone. Rising abruptly from brightly colored surfaces are countless black spires, serrate ridges, walls, and irregular masses of basaltic rock, agglomerate, and tuff. Within four volcanic fields, or widely dispersed, about 50 volcanic necks, 100 to 700 feet high, and 60 dikes, 10 to 900 feet long, have been mapped. In places, lavas cap mesas and protrude as palisade walls. Of the two huge laccoliths, Carrizo Mountain has been stripped down to its igneous core, but Navajo Mountain retains its original cover of sandstone. Thus the present topography of the Navajo country bears little resemblance to its earlier expression. The once fairly continuous surface is represented by a bewildering array of erosion forms among which the dwindling streams follow their tortuous courses. The outstanding elements of the landscape are mesa, butte, volcanic neck, canyon, and wash repeated indefinitely. Natural bridges, windows, arches, alcoves, cliff caves, and miniature erosion features of great variety and rare beauty stand as ornamental carvings on the larger architectural forms.

In its structural make-up the Navajo country is a region of rock flexures; the faults are few and of small dimensions. Characteristically northward-trending synclines and anticlines—both broad and narrow domical upwarps, and sharply delineated monoclines follow one another in succession and, in places, overlap or abut against each other. Ten major folds and eight minor folds, in addition to scores of local flexures, have been noted in the region between the Puerco and San Juan Rivers. In origin, most of these structural features are associated with the regional uplift from the Cretaceous sea. For a time they were concealed by the deposition of Tertiary sediments but since they have been exposed to erosion they have governed in various degrees the adjustment of streams and the development of the regional and the local topography. Some of the folds have been widely effective in preserving and obliterating the sedimentary rocks. Thus the central part of the broad de Chelly upwarp has been stripped down to Permian rock but at its eastern edge all of the Mesozoic formations are present in the steep Defiance monocline and extend long distances beyond. The Tusayan downwarp preserves Cretaceous strata that have been removed from surrounding areas. Likewise,

Figure 26.—Gypsum Canyon at mouth of Fable Valley in the Canyon Lands of southeastern Utah.

the symmetrical Gallup syncline has prevented the destruction of a commercially valuable coal field.

The Navajo country, substantially the Navajo Indian Reservation, is the home of approximately 56,000 Navajo Indians, most of them nomadic sheepmen who follow their flocks from place to place in search of forage and water, and of 3,700 Hopis who occupy ancient villages on mesa tops and derive their support from cultivated crops, chiefly corn. A prehistoric pueblo population is represented by cliff houses, especially well preserved in Canyon de Chelly and Tsegi Valley. The region is known chiefly to professional geologists, archeologists, and graziers. The absence of paved automobile highways and the restrictions imposed by the Bureau of Indian Affairs are deterrents to general travel. Passable roads connect the administration centers but reach few places of special scenic interest. In fact, some areas of considerable size await exploration.

San Juan Basin—At the eastern edge of the plateau province southward from the foothills of the San Juan Mountains at Durango, Colo., the land surface descends into the San Juan Basin—a topographic and structural depression that occupies about 12,000 square miles of northwestern New Mexico and adjacent parts of Colorado drained by the San Juan River system. The southern part of the basin is floored with nearly flat-lying Cretaceous sandstones, above which rise a few conspicuous mesas capped by rocks of Tertiary age; the northern part by southward and westward dipping Cretaceous sandstones overlain by Tertiary rocks that include shales, conglomerates, sandstones, and as much as 2,000 feet of volcanic debris. The strata in the basin have been deformed by several small folds and faults. The basin is conspicuously walled in on the west by the Hogback Ridge—a huge monocline, in which the Cretaceous beds are abruptly bent downward at angles exceeding 30 degrees. (Plate 13, Sec. 9, in pocket.)

Regional features of southern portion.—As defined in this report, the southern portion of the Colorado Plateau is that area, extending both north and south from the Grand Canyon and southeastward to the Arizona-New Mexico boundary, in which the rock sequence is chiefly of Paleozoic age. The plateau province to the north and east, including both the Navajo country and the canyon region of southern Utah differs from this southern portion chiefly in the character and sequence of the rocks. In both regions strata are flat-lying with the result that the processes of erosion have sculptured innumerable straight-walled canyons, mesas, and tablelands. In the southern area, however, the rocks are of an older group (Paleozoic) than those upstream (Mesozoic) and basic differences in these strata have profoundly affected various aspects of the landscape.

Contrast between physical features of the Grand Canyon district and those of the basin and range province to the south and west is great. The characteristically horizontal strata of the former are in marked contrast to the steeply tilted or much-folded layers of the other. Flat-topped hills and level skylines are replaced by jagged ranges and irregular peaks. Even where the same strata that form the walls of Grand Canyon are represented in mountains to the south and west, features of the landscape are totally different because of differences in rock structures.

The southern portion of the plateau province is divisible into 10 principal sections, separated one from the other by major lines of displacement such as faults or folds. Each section is in reality a block or segment of the earth's crust raised more or less vertically to its particular elevation high above sea level. North of the Colorado River at Grand Canyon are five of these segments or plateaus as shown on Plate 13, Section 10 (in pocket). Two others lie south of Grand Canyon, and an eighth extends southeastward forming the southern margin of the Colorado Plateau in this area. (Pl. 13, Sec. 12, in pocket.) Finally, near the New Mexico-Arizona boundary two additional sections are assigned to this province because of the similar rock types involved, even though the strata are more folded than elsewhere, making dome structures. (Plate 13, Sec. 11, in pocket.)

Within the plateau province and along its borders are areas of varying size, the surface features of which have been formed through the agencies of volcanism. Some of the features are spectacular; all of them have profoundly modified the general appearance and character of the landscape. Because they differ so from other features of the southern

plateau district, a separate treatment will be given the volcanic areas.

Plateaus on the north side of Grand Canyon.—The general character and geologic structure of the plateau blocks that form the north wall of Grand Canyon have been well-known since the early surveys made by Powell, Dutton, and others 60 to 70 years ago. The remarkable manner in which great segments of the earth's crust have been elevated along faults or fractures to form a series of steplike platforms, rising from west to east (Pl. 13, Sec. 10, in pocket), has been the subject of much speculation and has greatly influenced the development of ideas concerning the causes of mountain uplift.

Approached from the west along the Colorado River, the plateau province begins in Arizona, not far from the Nevada line, where a great cliff has been formed as a result of vertical movement of the area to the east along the Grand Wash fault. This upraised block is known as the Shivwits Plateau and extends from west to east for 30 miles. Its flat surface terminates abruptly against the face of a cliff formed by the Hurricane fault, and east of this is the higher Uinkaret Plateau. Two other faults, the Toroweap and Kanab, mark the western boundaries of successively higher plateaus still farther to the east. These are the Kanab and Kaibab. Finally the eastern end of the Kaibab Plateau, which has elevations up to 9,000 feet, is reached where the normally flat-lying rock strata are bent steeply downward in a monocline to the low level of the Marble platform. These four great blocks or plateaus form the northern rim of Grand Canyon, which is more than 100 miles long in air-line distance.

The Kaibab Plateau is by far the best known of the areas bordering Grand Canyon on the north. This is partly because it is more accessible and therefore better known than the plateaus farther west, and partly because its higher altitude affords a more attractive summer climate. Significant, however, is the fact that while many of the finest views of Grand Canyon are to be had from points along the margin of the plateau, such views cover only one part of Grand Canyon, whereas many superlative views of other and different parts can be obtained only from the more western areas. Furthermore, though the climate of the Kaibab favors summer recreation, it prohibits any appreciable winter usage, whereas the lower areas to the west can be visited during almost any season.

Geologically each of the plateau blocks is a modified repetition of the next. It is composed of essentially flat-lying strata such as are seen in the walls of Grand Canyon, but varying in proportion and in detailed character so that over many miles the surface expression of the rocks is quite distinct. Thus, the wide, green bench of shale that forms the well-known Tonto platform of eastern Grand Canyon gradually disappears westward, whereas the broad, red esplanade of western Grand Canyon is a negligible feature in the east as a result of the thinness of the Hermit shale there. The significant point, therefore, concerning the Grand Canyon as a great spectacle with unusual inspirational value is that it is distinctly different in different parts, yet large and impressive throughout.

Notable exceptions to the general uniformity in geological features of the plateau are those developed by volcanic activity. In both the Uinkaret and Shivwits divisions, extensive flows of lava and numerous small craters and cinder cones blanket large parts of the surface, thus giving a new character and added interest to the region. In Toroweap Valley on the Uinkaret Plateau, this display of volcanism is especially fine and constitutes an exhibit of exceptional value which has as yet been but little appreciated. The freshness and recency of some flows, the symmetry of many craters, the spectacular manner in which lavas have cascaded over canyon walls, examples of lava dikes leading upward from the depths, and, above all, the complex interrelationship between erosion of the canyon on the one hand, and the piling up of volcanic matter on the other, make this area outstanding as a place for stimulating the mind and furnishing inspiration.

The Hualpai Plateau.—The southwesternmost section of the Colorado Plateau, bounded by the Colorado River on the north, the Grand Wash and Aubrey Cliffs on the west and east, respectively, and the Juniper Mountains on the south, is commonly termed the Hualpai Plateau. The Hualpai Indian Reservation occupies a large part of this area.

In geologic structure the Hualpai Plateau is similar to the adjoining plateaus. It is formed of

essentially flat-lying strata of sedimentary rock that have been uplifted as a block or series of blocks along great fault lines that traverse the region with a general north-south trend. The largest of these faults are the Grand Wash and Aubrey, although others of considerable magnitude also cross the region.

The surface of the Hualpai Plateau, about 5,000 feet in elevation, is somewhat lower than that of neighboring plateaus because the several uppermost formations in the others have here been stripped away by long erosion. On the other hand, the surface of the Hualpai is everywhere 2,000 to 3,000 feet higher than the desert valleys to the west and south, causing it to have a temperate climate and to be favorable for year-round recreational use.

The geological features of this region are primarily those of the Grand Canyon, which forms its northern boundary. Surface rock over most of the area is massive gray limestone of the uppermost Redwall (Mississippian), although locally beds of red Supai sandstone (Permian) remain above this, and elsewhere Devonian strata have been faulted up to the surface. Where the river has cut through these strata, forming Grand Canyon, there is a drop of about 3,000 feet and the canyon walls have the appearance of being nearly sheer. This accounts for many fine and spectacular views along the rim, as at Quartermaster Canyon and Bridge Canyon in the west and above Granite Park farther east.

Geology of the Hualpai Plateau is similar and related to that of eastern Grand Canyon, yet it is different enough to be worthy of special consideration. In addition to the broad aspects of stratigraphy and structure, there are such special features as Rampart Cave, where prehistoric animals, notably the extinct ground sloth, are buried in great numbers. The green and purple shales at Columbine Falls also contain quantities of well-preserved Cambrian trilobites.

Coconino Plateau.—The Coconino Plateau, extending from Grand Canyon south to the San Franciscan volcanic field (see Pl. 13, Sec. 12, in pocket) and from the Aubrey Cliffs east nearly to the Little Colorado, is the best known of the plateau blocks within the Grand Canyon province. It is composed of essentially flat-lying strata with resistant Kaibab limestone of Permian age forming the surface. Along the eastern margin the strata are folded into a monocline, causing them to dip under more recent rocks of the Painted Desert. Elsewhere in this plateau and along its western margin, strata have been broken by faults of varying magnitude. In general, however, the geologic structure is very simple.

Eastern Grand Canyon, of which the Coconino Plateau forms the southern rim, is the outstanding feature of this area. Included is the most frequently visited and best known portion of Grand Canyon. As part of a national park, its recreational aspects have been carefully studied and partly developed.

Throughout the Coconino Plateau are many minor features of geologic significance some of which, through proper development as places of interest to the visitor, would add to the recreational assets of the area. Included in this category are solution phenomena formed in the surface limestone by rain and snow waters. Examples are the Citidel fissure and Doney fissure northeast of the San Francisco Mountains, Bottomless Pits near Walnut Canyon, and the caverns south of Ashfork. Another type of feature is represented by Grand Falls of the Little Colorado. It is formed where an ancient lava flow blocked the stream course and caused the river to drop over a limestone cliff, making an inspiring sight, especially in flood season. Farther downstream is the canyon of the Little Colorado, remarkable for its proportions. It stands out in a region of canyons as one of the narrowest and most sheer-walled. Excellent views into its depths may be obtained at a few places along the Grand Canyon-Cameron highway, but much more might be done to take advantage of the canyon's inspirational and educational possibilities. Salt Springs near its mouth, where Hopi Indians obtained their main supply of salt for years, is a little-known place of considerable historic interest.

East of the San Francisco Mountains toward Winslow is Meteor Crater—one of the most remarkable features in the United States and one that is internationally known. Today, a preponderance of evidence seems to favor the theory that this pit is the result of impact and explosion of a meteorite from outer space, but whether this be true or, as some scientists have suggested, a volcanic steam

explosion was responsible, the crater is unique in character.

The Mogollon Plateau.—The Mogollon Plateau is a southward and a southeastward extension of the Coconino Plateau. These two sub-provinces are similar in geologic structure and age, but are separated by the San Francisco volcanic field. (See Pl. 13, Sec. 12, in pocket.) In both, the surface is formed largely of resistant limestone of Permian age and the strata are essentially horizontal, being disturbed only by a few breaks or normal faults and by monoclinal folds. The Mogollon Plateau ends abruptly on the south and west where high escarpments form what is known as "the Rim." Beyond this, low valleys give a very different aspect to the country.

Most of the Mogollon Plateau is covered with forests which, together with the cool summer climate, make it favorable for recreational development. Springs are not abundant but are scattered throughout the area. Relatively small, but narrow and attractive little canyons such as Chevelon, Black, Clear Creek, and others, dissect its surface. Cutting back into it from the adjoining valleys to the south and especially to the west are some large and colorful canyons that are very scenic. One of these—Oak Creek Canyon—is readily accessible by a main road and is a very popular resort area offering fishing, swimming, and exceptional scenery. Some of the others, such as Beaver Creek and Fossil Creek, are attractive and interesting, but less known.

Of special geologic significance in the Mogollon Plateau area are coal deposits located in the eastern part of the area near to the rim, and "the Sinks" which are to the north of this area. "The Sinks" consist of 30 or 40 bowl-shaped depressions in limestone, ranging from a few yards to about one hundred yards in diameter, formed by the solution work of water. Lesser features of interest are the spectacular dikes of black lava that extend through red sandstone in the walls of Oak Creek Canyon and the examples of columnar jointing in lava at the head of this canyon.

Defiance Plateau. — Immediately west of the Arizona-New Mexico line from the vicinity of Houck on Highway 66 almost to the border of southern Utah is an upwarped area named the Defiance Plateau. Strata of Paleozoic and earlier age, comparable to those on the Mogollon and Coconino Plateaus to the south and west, appear here at the surface, folded into a large anticline along a north-south axis. (See Plate 13, Sec. 11, in pocket.) Near the center of the fold, in Quartzite Canyon, very ancient quartzites project through the red shales and sandstone, showing that for vast ages an old land mass remained in this area while seas came and went around its borders.

The magnitude of the uplift, together with the massive character of the sandstone involved, resulted in the erosion of numerous deep and spectacular canyons in the flanks of the anticline. Most notable are Canyons de Chelly and del Muerto, although lesser canyons such as Nazlini are also colorful. From a geological standpoint these and related features of erosion compete with the antiquity and history of the quartzite core for major interest.

Southwest of Fort Defiance is a natural bridge of spectacular character carved in the red de Chelly sandstone. It is one of many scenic features sculptured by erosion along the flanks of this plateau.

Zuni Mountains.—The Zuni Mountains of New Mexico are interesting geologically because they represent an uplifted area the surface features of which have been considerably modified through erosion. Structurally the area is similar to the Defiance Plateau to the northwest in Arizona in that there is a massive core of very ancient rock flanked by younger strata. In the Zunis, granite forms the core and red sandstone of Permian age has been deposited around the margins. This structure is significant from the standpoint of historical geology for it represents a positive area or region that stood above sea level during millions of years (Paleozoic) while marine waters from several directions periodically advanced toward and retreated from it.

EASTERN BORDER LANDS OF COLORADO PLATEAU

The Green River Basin, the Uinta Mountain region, and the Colorado Plateau, which constitute by far the greatest and most characteristic part of the vast region drained by the Colorado River north of central Arizona, are relatively simple in topographic expression, physiographic expression,

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and physiographic history. Bordering this central region on the east and still within the Colorado drainage basin is a belt of unusual topography developed on rock complex in structure, composition, and relationship. Particularly noteworthy are the lands along the Upper Colorado, the Gunnison Valley, and the San Juan Mountains.

Upper Colorado River Valley. — In geologic make-up, scenery, and recreational resources, the valley of the Colorado River in north central Colorado is totally unlike its expression elsewhere. The landscape is that characteristic of the Rocky Mountains rather than of the plateau country. In the place of flat lands, vertically walled canyons, and cliff-bound mesas and plateaus, fairly simple and regular in topographic form and stratigraphic details, there is an aggregation of saw-toothed ridges, ragged peaks, abraded highlands, glacial cirques, and flat-floored "parks" whose origin and interrelations are difficult to interpret. The Upper Colorado and its tributaries flow in a succession of wide and narrow canyons and valleys with flaring sides, over plains, across anticlines, synclines, and faults, and from place to place trench schists, lavas, sedimentary rocks, and alluvium of varied composition and attitude. The larger tributaries have cut their way far into the granite core rocks along the Continental Divide—past the axis of the Rocky Mountain uplift — and thus bring into the Colorado drainage basin most of the water that falls on the lofty, glaciated Park Range, Gore Mountains, and the Sawatch Range, which culminate in the highest peaks of the Rockies. In the Sawatch Range about 25 peaks exceed 13,000 feet, and 10 exceed 15,000 feet. The Roaring Fork has cut from the granitic Sawatch mass the equally high Elk Mountains — a much deformed anticline of Carboniferous rocks —into which many dikes and sheets of igneous rock have been intruded. Because developed in rocks of different hardness, attitude, and stratigraphic sequence—flat lying and tilted sandstone, limestone, shale, and lavas—the remarkably sinuous streams flow swiftly between close-set vertical rock walls, between slopes gashed by ravines, or meander leisurely across wide alluvial flats. A traverse of Eagle River, the Roaring Fork, or the Colorado above the brightly colored canyon at Glenwood Springs reveals a succession of fascinating vistas, tumbling waters, quiet waters, pasture land, grain fields, farmhouses, and above the valley walls, snow-capped mountains.

An outstanding feature of the Upper Colorado Valley is the White River Plateau, about 40 miles in diameter and 10,000 to 12,000 feet above sea level (Pl. 13, Sec. 6, in pocket)—a flat-topped highland bordered by steep slopes and structurally an uplifted mass in which the deformation of its component strata is restricted to its rims. At its western edge the Grand Hogback, composed of thick Cretaceous and thinner Jurassic and Triassic strata with dips as great as 30 degrees, emerges from the adjacent Tertiary floor and stands as prominent ridges, 600 to 1,000 feet high. From the hogback across the plateau top, nearly horizontal Paleozoic rocks form the surface, and at their eastern limit are overlapped by steeply tilted Mesozoic beds, the remnants of strata that once overarched the plateau and joined those in the Grand Hogback. To attain their position and altitude, the sedimentary rocks inside the tilted borders of the plateau must have been uplifted en masse as much as 14,000 feet (early Tertiary time), then stripped down to a somewhat uneven surface over which lava in extensive sheets was poured out (Quaternary time). At the present time the plateau is a single topographic unit, the source of streams that flow to the Yampa, the White, and the Colorado, but as a regional structure once extended southwestward across the Colorado River, Eagle River, and Roaring Fork. Its major characteristic features in modified form are represented in Red Table Mountain and adjacent lava-capped mesas and its western terminus, the Grand Hogback, is traceable for 80 miles.

Gunnison Valley.—South of the Elk Mountains the landscape presents features not represented elsewhere along the eastern edge of the Colorado drainage basin. Above a general surface, developed on Cretaceous rocks at an average altitude of about 8,500 feet, rise low domes of metamorphic and igneous rocks — the uneroded remnants of a former peneplain. In the West Elk Mountains, masses of intrusive porphyry culminate in isolated peaks that rise as much as 1,500 feet above the upturned edges of the strata that once arched over them. The dominating surface features are thick, widespread accumulations of volcanic breccia and tuff—in one

area continuously covering about 400 square miles —and extensive sheets of rhyolitic and andesitic lavas. Into the regional surface the Gunnison and its tributaries have sunk deep runways by cutting through sedimentary, igneous, and metamorphic rocks down to porphyritic granite.

The present scenic features of the Gunnison Valley record merely the last event in the long geologic history of the Rocky Mountains and the Colorado plateaus. In Cretaceous times the region was covered by the sea, in which sediments of great thickness accumulated, then near the beginning of Tertiary time was uplifted as a great arch—the ancestral Rocky Mountains. During the long period of erosion that followed, the sedimentary rocks that once were continuous across its surface were stripped away, down to the core of the schist and granite, leaving an erosion surface of moderate relief; a broad belt that extends from the Sawatch Range westward about 70 miles, and southward merges with the foothill slopes of the San Juan Mountains. The latest major movement of the earth's crust was upward and brought the Sawatch Range and its bordering lands along the Gunnison to their present lofty position, and perhaps coincident with the uplift the newly exposed surface was flooded with lavas or buried beneath volcanic tuffs. Then followed a period of erosion whose length is the life span of the present-day streams. The progress of the streams in developing valleys and cutting channels in rocks of various types is faithfully recorded by the Gunnison River. For about 100 miles of its upper course (Tomichi Creek) the river occupies alternately shallow canyons in intrusive granite and open valleys in less-resistant Cretaceous and Jurassic rocks. Farther down it flows between vertical walls of dark-colored contorted schists and gneisses through the spectacular Black Canyon, 1,700 to 2,400 feet deep and in places not more than 50 feet wide at the bottom. The Pre-Cambrian rock in the canyon walls terminates abruptly at an eroded surface above which stratified rocks of Upper Cretaceous age form slopes. The division line between these unlike rock masses represents a hiatus in the geologic time scale of an estimated 400,000,000 years. That the Gunnison is a superposed stream that has persisted in the course established on a surface high above its present walls is shown by its entrenched meanders and its topographic position. It has continued to cut its path across highlands through hard Archean schists, seemingly ignoring the soft rocks in the adjacent, downfaulted lowlands.

San Juan Mountains.—The dominating topographic feature of southwestern Colorado is the San Juan Mountains, which lie athwart the Continental Divide and cover an area of about 6,500 square miles. (Pl. 13, Sec. 8, in pocket.) The western part of this lofty-peak-studded mass lies within the Colorado drainage basin and is the gathering ground for the waters carried northward directly to the Colorado by the Uncompahgre, San Miguel, and Dolores Rivers, and southward by the La Plata, Animas, Los Pinos, and Piedra Rivers which reach the Colorado River by way of the San Juan. Through the escarpment that walls in the mountains, these streams descend precipitously to the adjacent plateau lands. The average altitude of the main mountain mass including the western San Juan Mountains, the north-trending Cimarron and Mount Sneffels spurs, the Needles Mountains, and the somewhat isolated San Miguel Mountains is about 11,500 feet. Scores of peaks rise to heights of 13,000 feet, 13 exceed 14,000 feet, and the canyon floors lie 4,000 to 6,000 feet below the adjacent summits. The mountains consist almost entirely of Tertiary volcanic rocks; lavas, stratified tuffs, agglomerates, and breccias, 5,000 to 9,000 feet in thickness, with which are associated igneous intrusives. Mesozoic and Paleozoic formations are exposed in the deeper canyons, and along the edges of the mountain mass they appear in sequence beneath the volcanic cap, and dip north, west and south, and within short distances from the mountain center assume a horizontal position.

Compared with adjacent regions, the San Juan Mountains are a deeply, though not intricately, dissected rock-surfaced plateau in which the forms of many peaks, ridges, and canyons have been modified by glacial erosion. Their present features record merely the latest major event in a long, complex geological history. As revealed by the composition and arrangement of the exposed rocks, an enormous basal mass of Pre-Cambrian and Cambrian schists, porphyries, and quartzite was worn down, then overlaid by Paleozoic sediments 2,000 to 4,500 feet thick—most of them deposited in a

sea. Near the close of Paleozoic time the strata were folded, broken, locally uplifted, and then eroded to a surface of small relief, upon which were accumulated sediments of Mesozoic age to an estimated thickness of about 6,000 feet. Near the close of the Cretaceous period, when much of the region was below sea level, areal disturbances in the earth's crust, accompanied by volcanic activity, pushed the strata upward as a broad dome—the ancestral San Juan—far higher than the existing mountains. The uplift continued into early Tertiary time, attaining altitudes that permitted glaciation—a very rare episode in Pre-Pleistocene geologic history. Erosion also continued until the highland mass was reduced to a roughly level surface. Then followed the deposition of great beds of tuff and lava, for which the region is famous. With the cessation of volcanic activity, stream erosion once more became the dominant geologic force. On the widely spread volcanic rocks, streams tributary to the Colorado established their courses and renewed uplifts so increased their power that by the end of the Tertiary era the irregular mountain mass had been reduced to the San Juan peneplain, a generally even, regional surface above which rose residual peaks. Later uplifts introduced the present cycle of erosion, during which the extensive peneplain has been trenched by great canyons and its summit and edges modified in form. Even during Quaternary time the San Juan region has been subjected to almost continuous crustal warping, and sculpturing by vigorous streams has been interrupted only when the region was mantled by ice. During the Pleistocene epoch, except for the high peaks which doubtless were covered by snow, the summit lands were buried by ice to depths of 500 to 1,000 feet, and more than 30 ice streams 5 to 50 miles long flowed down the valleys to the mountain base. The effects of glaciation, repeated three times, are everywhere plainly recorded in ice-scoured surfaces, cirques, widened valleys, moraines, outwash plains, and scores of lakes. Durango, La Plata, Silverton, Ouray, Ridgeway, and several other villages are situated on glacial debris. Furthermore, the steepening of valley walls by glacial scour in conjunction with heavy rainfall has provided conditions exceptionally favorable for the transport of material en masse. In the San Juan Mountains more than 300 landslides, 100 rock streams, and many mud flows and soil creeps have been mapped; masses of moving debris that cover ½ to 2 square miles, extend up canyon walls to heights of 1,000 to 2,600 feet above the stream beds and some distance down valley—the Slumgullion flow for 6 miles.

Though the picturesque erosion forms characteristic of the plateau province are lacking, the San Juan landscape is truly magnificent. The grandeur of the desolate summit lands—bare rock flats, huge domes, lofty pyramids and needles—is matched by the majesty of the gigantic canyons. For the scientist the region has special interest. It reveals chapters in geological history and displays physiographic features not duplicated elsewhere. Here the whole story of glaciation is easy to read, and such features as the great rock streams and mud flows are fully displayed.

WESTERN BORDER LANDS OF COLORADO PLATEAU

In topographic expression, the western border of the Colorado drainage basin is radically unlike the eastern border. In contrast with large eastern tributaries to the Colorado River, which generally rise along mountain crests at the Continental Divide and flow across Pre-Cambrian granite and Paleozoic rock, most of the western tributaries are short, carry little water, and occupy channels cut in sedimentary rocks of Mesozoic and Tertiary age. Along the Wyoming-Idaho boundary and in the Uinta Mountains some streams rise in highland valleys, but in Utah most of them originate on plateau escarpments, and in Nevada on flat lands or the slopes of scattered mountains. Across the tops of the high plateaus the drainage divide between the Colorado Basin and the Great Interior Basin is difficult to trace, and even more difficult where it lies on the slopes of Pine Valley, Snake, and Sheep Mountains, and crosses Charleston and New York Mountains. Southeastern Nevada is part of the Colorado drainage system with topographic features characteristic of the basin and range province.

In the area drained by the Virgin River, some of the little-known faulted mountainous masses are composed of Paleozoic rock; some, like Beaverdam and Virgin Mountains, of Pre-Cambrian schists overlaid by Paleozoic strata; and others, like the Muddy and Spring Mountains, of thick Paleozoic

and equally thick Mesozoic formations. The character of this region is described in the section of this report concerning the basin and range province.

ARIZONA MOUNTAIN PROVINCE

This province, as described in this report, refers to the area along the south margin of the Colorado Plateau occupied by certain outliers which structurally resemble the plateau but which appear very different because they are eroded into rugged mountains.

Like the Grand Canyon province, this province is formed of large upraised crustal blocks or segments. Here, however, the rocks forming the surface are not flat-lying sedimentary types of Paleozoic age as at Grand Canyon, but granite and metamorphic rocks of earlier age. The result is that erosion has sculptured them into forms very different from the characteristic mesas and buttes of the plateau. Outstanding examples of these outliers are the granite masses around Prescott, Ariz., the Mazatzal and the Sierra Ancha Mountains. Between these are some large valleys, including those of the Verde River and Tonto Creek, which have distinctive character and are of exceptional interest from a geologic standpoint.

Prescott Area.—The mountainous region about the town of Prescott, in central Arizona, is largely composed of granite. It weathers into rugged hills and irregular surfaces that are in marked contrast to topographic features of the plateau area farther north. This granitic area extends eastward to the Verde Valley, north to Chino Valley, west to the Aquarius Cliffs, and south as far as Yarnall Hill. Lavas cover and conceal the granite across some rather extensive portions of the region, locally modifying the general appearance of the area. For the most part, however, the vast granite mass dominates the landscape.

Along the eastern borders of the Prescott Mountain area, faulted blocks, formed of sedimentary strata resting on granite, are preserved, indicating that this entire region once was covered with strata such as now form the plateau province. An enormous amount of erosion, therefore, must have stripped away the overlying sediments here, leaving the great granite core to form the present land surface. Peculiar rock forms resulting from this erosion, as illustrated by the Granite Dells, are among the most interesting features of the area.

From a geologic standpoint, the most significant elements of the Prescott area are those that have to do with ore deposits. Great ore bodies have been brought up by faulting, especially along the border areas, and many mines have been developed in this region as a consequence.

Mazatzal and Sierra Ancha Mountains.—South of the Mogollon Plateau and east of the Verde Valley is a portion of central Arizona that differs geologically from other parts of the State. It consists of two great mountain blocks—the Sierra Anchas on the east and the Mazatzals on the west—separated by the Tonto Basin. The ranges which extend for many miles along north-south axes are eroded into jagged, irregular skylines, resembling the mountains of the basin and range province to the south. Structurally, however, they appear to be more closely related to the plateau, having been raised vertically as great blocks, the upper parts of which were long ago removed by erosion. Very ancient quartzites (Algonkian) form the present mountain summits, whereas in the plateau to the north, rocks of corresponding age, if they occur at all, lie buried at great depths.

The height of the mountains (Aztec Peak in the Sierra Anchas, 7,400 feet), the abrupt rise above the surrounding valley floors, and the ruggedness of the terrain combine to make the Sierra Ancha-Mazatzal Mountain area one of the wildest, least accessible parts of Arizona. Vegetation is dense over wide areas and wildlife is abundant. In general, this area is one of the most favorable places for recreational development of the type that involves hunting, camping, and hiking.

Among features of outstanding geologic interest in this area are the asbestos deposits high in the Sierra Ancha Mountains. They appear as a conspicuous white line when seen from a distance. Similar asbestos deposits are found in other parts of this area, notably in Salt River Canyon.

Between the Sierra Ancha and Mazatzal Mountains, near the town of Payson, Ariz., is a natural bridge which has been developed in limestone through the work of solution. It is large enough to

have a small orchard on top and should attract considerable interest.

Verde Valley.—The walled-in Verde Valley differs in physiographic character from other large valleys in Arizona, yet it is one of the most delightful because of the large permanent stream flowing down its length. On three sides the valley is enclosed by cliffs forming the margins of upraised blocks of the Colorado Plateau. Details of geologic structure have not yet been determined in this area, but a series of great vertical faults apparently controlled its early development. Erosion has since greatly modified the escarpments on each side and partly obliterated evidence of the crustal movements involved. Lavas formed a dam across the river in one place and extensive deposits of limestone are the result of deposition in a very large lake that once covered much of the valley. Because of this complex history, many geologic features of unusual interest are represented in the Verde Valley.

Unlike the dry plateau country of northern Arizona or the mountain ranges to the south, Verde Valley is destined, both because of its character and location, to be developed as an important source of water and of agricultural produce. Among the best-known features of this area deserving consideration and more study are Verde Hot Springs, Soda Springs, fossil tracks of lions and other prehistoric mammals, salt deposits and prehistoric salt mines, and lake deposits with mollusks.

RECENT VOLCANIC AREAS

Within and along the borders of the Colorado Plateau are several areas of geologically recent volcanic activity which have so modified both the appearance and the character of the country as to merit special treatment in this report. Although underlain by normal strata of the plateau type, lavas, cinder cones, and strata volcanoes have covered and masked the sedimentary rocks, thus obscuring the original topographic forms. Outstanding examples of such areas are the San Francisco Mountains and the White Mountains. A lesser example is found in the Mount Trumbull region.

San Franciscan volcanic field.—One of the largest, most spectacular, and probably the most interesting geologically, of the volcanic fields within the Colorado River watershed is that developed about San Francisco Mountain in the central part of Northern Arizona (Pl. 3, in pocket). This lava field covers an area of approximately 3,000 square miles. In addition, several hundred small cinder cones are scattered over this surface, and a series of five large strato-volcanoes form a row from east to west, dominating the landscape. San Francisco Mountain, the largest of the volcanoes, reaches an elevation of 12,611 feet above sea level or about 5,000 feet above the plateau surface.

The age of the various volcanic features in this area varies considerably, for the results of three distinct periods of activity can be recognized. The oldest of these, which was a time when very extensive basic lava flows poured forth on the surface of the plateau, dates back at least a million years (Pliocene). During the middle period the high peaks were formed of more viscous lavas. The last period, like the first, was featured by vast sheets of basalt spreading over the surface and by the development of small cinder cones, but it is most notable because of its recency. One cone, Sunset Crater, is less than a thousand years old.

The diversity of features represented and the excellent state of their preservation due to recency of origin combine to make this an outstanding area for illustrating volcanic phenomena. Most of these features are well known to scientists through the works of Robinson and Colton; some of them are familiar to the general public through the educational programs of the National Park Service and U. S. Forest Service, the agencies which control a large part of the area. Still, much remains to be learned about the various features and only a beginning has been made in utilization of the recreational possibilities of this area.

Features of special geological interest in the San Franciscan volcanic field, having potential value from an educational and inspirational standpoint, range from entire mountains that illustrate the results of remarkable or unusual processes to small detailed structures or products incidental to the volcanism. In the former category are Slate Mountain and Marble Mountain, which are excellent examples of semi-laccoliths—small hills due to the partial doming up of once flat-lying layers of sedimentary rocks through the force of molten material

being introduced from below. The structure in these hills is easy to see and presents an impressive story when understood, especially in Slate Mountain, where a road affording spectacular views makes many of the features readily accessible.

Sunset Crater, a recent cinder cone preserved as a national monument, already has received recognition as an outstanding natural feature, though only a beginning has been made in presenting its story so that the layman can see and understand it. Another cinder cone of unusual interest, and one that is little-known, is Red Mountain. Erosion has cut away the north side of this cone, clearly exposing to view the sloping layers of bright red cinders, thus demonstrating the manner in which it has been built up.

Among features of special interest on San Francisco Mountain are evidences of glacial activity including moraines and outwash plains, areas of obsidian or volcanic glass, and plugs or necks showing where molten material came up through the interior at several different times. Features of the adjoining volcanic field that deserve mention because of their unusual character are the "squeeze-ups" and ice cave near Sunset Crater, the large lava tube known as Government Cave, and the Grand Falls of the Little Colorado formed by a lava dam.

White Mountain volcanic field.—Along the southeastern margin of the Colorado Plateau in Arizona, east of longitude 110°, the plateau surface and much of the area to the south is thickly mantled with volcanic rocks of relatively late geologic age. The highest elevations are reached at such important centers of eruption as Ord Peak and Mount Baldy, around 11,000 feet. Southward from here, the volcanic field includes the Blue Range and extends to the vicinity of Clifton and Morenci. Eastward, it goes far into New Mexico, while in the west, many lava flows extend down into the Apache Indian Reservation, especially in the area east of Eagle Creek and north of the Gila River, on the Natanes Plateau south of the Salt River, and down Forestdale Creek farther north.

The mantle of igneous rock forming this volcanic field varies greatly in thickness and in com-

Figure 27.—Sunset Crater in Arizona.

position, and rests upon different types of surface from place to place throughout the region. Along the northern margin between Springerville and Snowflake, it consists of only a few relatively recent, flat-lying flows of basalt with small, partly-weathered cinder cones superimposed. Farther south toward Alpine, the volcanic series is much thicker and includes many deposits of soft tuff, but cinder cones are lacking. South of this area, where the scenic Coronado Trail reaches its highest elevations, deep canyons dissect the mountains and show that the landscape is formed of a great number of flat-lying basaltic flows with a total thickness of thousands of feet. Such vast outpourings of lava are unexcelled elsewhere in this region and represent a truly impressive volcanic history.

Along the Coronado Trail south of Rose Peak, the volcanic rocks exposed to view are largely silicic or intermediate in composition, in contrast to the basic types farther north, and they are much folded and faulted. Furthermore, these lavas probably are considerably older than the basalts and at one time were covered by a southward extension of the basic lavas. Westward from this area across the great valley of Eagle Creek, the products of volcanism cover the surface for many thousands of square miles. Flat-lying sheets of relatively recent basalt, locally with beds of tuff, cover all of the Natanes Plateau and the area northward.

Examination of the volcanic rocks along the western margin of the field, that is, in the San Carlos and Fort Apache Indian Reservations, shows that strata of sedimentary rocks upon which the lavas rest are progressively younger and higher in altitude from south to north. In all of this area the underlying formations remain in a nearly horizontal position, having been uplifted vertically as in the Grand Canyon area. Near San Carlos, however, the basalts rest on a surface of Mississippian limestone. Near Fort Apache and White River the black lavas are on red Supai sandstone, and far to the north they are underlain by Permian limestone and later formations typical of the Grand Canyon and Navajo countries.

Geologic features of this volcanic field that have outstanding scenic interest include the deep canyons eroded by the Black and the White Rivers, the narrow gorge of the Blue River, and the black volcanic necks or plugs that rise spectacularly above the red standstone east of Fort Apache and once served as feeders to lava flows long since removed.

Uinkaret and Shivwits Plateau volcanic fields.— The two westernmost plateau blocks north of Grand Canyon, known as the Uinkaret and Shivwits, are centers of relatively recent volcanic activity. Although these volcanic fields are small beside the San Franciscan and White Mountain fields to the southeast, they contain many elements of interest, especially in areas where the lavas and craters are in proximity to the rim of Grand Canyon. The outstanding features of these areas are discussed in this report, in the section on "Plateaus on north side of Grand Canyon."

BASIN AND RANGE PROVINCE

The term "basin and range" is applied to a type of country formed of long, usually parallel, mountain ranges separated by flat alluvial plains which are the result of mud, sand, and gravel filling former intervening valleys of considerable depth. West and south of the great plateau is a vast, low desert region, traversed by the lower part of the Colorado River and drained by its tributaries such as the Gila and Salt Rivers. Geologically speaking, this is but a part of the entire area commonly designated as the basin and range province, which includes the interior drainage of the Great Basin and parts of certain other watersheds.

Mountain ranges within the basin and range province are of many types whether classed according to structure or rock character. Most of them trend from northwest to southeast, though there are notable exceptions. Some of them are composed largely of stratified sedimentary rocks, some are granitic or metamorphic masses, and still others are dominantly of recent volcanic rock. A majority contain combinations of these materials. Certain of the ranges owe their present positions to the simple tilting of strata along nearly vertical fault planes, whereas others are the result of folding, overthrusting, or complex combinations of these processes. Various parts of the province can be classified and grouped in a rough way according to these characteristics. The treatment in this report follows such natural groups.

The principal subdivisions of the basin and range province as recognized here are (1) the sedimentary ranges of the Arizona-Nevada corner; (2) the desert ranges south of Lake Mead; (3) the east-west trending ranges of middle western Arizona; (4) the southeastern Arizona ranges; (5) the southwestern Arizona ranges; and (6) the Colorado River delta, and Salton sink area.

Arizona-Nevada corner.—That portion of the basin and range province that includes the southern part of Nevada, northwestern Arizona, and southwestern Utah differs from neighboring parts of the province in the Colorado River drainage in that most of its ranges are formed largely of the same sedimentary strata found in the adjoining Colorado Plateau. These ranges, in general, have a north-south trend, but they differ considerably in structure. Some are relatively simple, being formed by the tilting of rock layers through movement along normal faults, but others are extremely complex and involve folding, thrust faulting, and several stages of normal faulting.

The Muddy Mountains and the Spring Mountains represent the more complex types. Overthrusting of rock strata on a huge scale is especially well illustrated and easy to see in the Muddy Mountains and might well be featured as an educational exhibit. Folding, compound normal and reverse faults forming wedges of strata, and examples of rock replacement near faults can be well illustrated in both ranges.

Examples of mountains developed with simple structure are the ranges through which have been carved Iceberg and Grand Wash Canyons on Lake Mead. These are particularly good illustrations of the effects of crustal disturbances, both because of the spectacular character of the ranges and because of their easy accessibility by boat. They also offer unusually good opportunities for illustrating to the layman the basic geologic principles involved in contrasting types of deposition, cyclic sedimentation, and differential erosion, all of which are shown especially well by the colorful beds forming the walls of these canyons.

Other ranges in this area which are relatively simple in structure, and therefore easy to understand, are the Frenchman, the Virgin, and the Beaver Dam Mountains. Steeply tilted layers of rock are readily apparent in all of these and usually attract the attention of the visitor. The Frenchman Mountains as seen from the air near Las Vegas Airport are especially striking.

In addition to large-scale structural features of the mountain ranges, this portion of the basin and range province contains an abundance of other geological features having interest and significance, many of which should be considered in developing a recreational program. Among these are (1) Gypsum Cave, Nev., where traces of early man were found associated with remains of extinct animals; (2) extensive lake deposits resting high above Lake Mead and illustrating clearly the former presence of a large natural lake in this area; (3) dikes of volcanic rock intruded into other rocks as illustrated especially well by the black dike in gravels by the highway south of Hoover Dam; (4) excellent illustrations of angular unconformities to be found in several places along Lake Mead and elsewhere in the region; (5) erosional controls in forming spectacular mesas of gravel as shown by the Temple, Napoleon's Tomb, and other hills near Lake Mead; (6) the remarkable erosional features developed in red sandstone at the Valley of Fire; and (7) deposits containing mammoth remains east of Las Vegas.

Desert ranges south of Lake Mead.—A large section of the basin and range province in northwestern Arizona contains north-south trending mountains composed partly of very ancient crystalline rocks and partly of geologically young (Tertiary) volcanic rocks in varying proportions. Sedimentary strata are absent. This type of desert topography extends over a large area from Lake Mead on the north to the vicinity of Topock on the south; from the Grand Wash Cliffs on the east to and beyond the Colorado River on the west. It is a region of rugged mountain ranges with mining operations in many places.

The Black Mountains are the largest desert range in this area. They are 100 miles long and reach heights of more than 5,000 feet at Mount Perkins and Mount Wilson. At their northern end, where they are cut through by the Colorado River, Hoover Dam has been constructed. From this locality southward, the range is paralleled on the west by the Colorado. Perhaps the most unusual element

of the entire range is Fortification Hill—a lava-capped mesa of light-colored fanglomerate, near Hoover Dam.

East of Black Mountains, across Detrital Valley, are three other prominent ranges of somewhat similar character. From north to south, they are the White, Cerbat, and Hualpai Mountains. The last-named is the largest and highest, reaching an altitude of about 7,500 feet, and has an abrupt western front caused by a large fault. Already, advantage has been taken of the summit's cool climate and good views with the development of a county recreational area.

The broad geologic features are simple in most parts of this area where many flows of black basalt may be seen, one upon another or resting on an old eroded surface of granite and schist. On the other hand, details of structure in the older rocks are difficult to work out for they are much altered by metamorphism and intrusion. The region as a whole is inhospitable both because of the very hot summer climate and because of the barrenness of most of the ranges. Some geological features, such as a prominent lava dike that cuts through gravels along the highway to Hoover Dam, might be made interesting to visitors, but opportunities are limited.

East-west trending ranges of middle western Arizona.—In contrast to the north-south trend of most mountains throughout the basin and range province, those ranges forming a belt across middle western Arizona are oriented in an east-west direction. These mountains are largely of very ancient crystalline rocks, although some also contain remnants of sedimentary strata of Paleozoic age. Furthermore, late basalts are common in places. Most of these ranges have complex structure, resulting from a long history of crustal disturbances. Extensive overthrusting of great mountain blocks has been recognized in various localities.

Prominent among the east-west trending ranges of western Arizona are the Bucksin, Harquahala, and Huarcuvar Mountains in Yuma County, and the Vulture Mountains in Maricopa County. All of these are typical desert ranges of considerable interest from the standpoint of geologic structure and mineral wealth. The structure is very complex but in other respects there is nothing outstanding about the mountains. In general, they are relatively low in altitude.

The Mohave Mountains in southern Mohave County probably also should be included in this group. The western part of these mountains is formed of volcanic rocks and in them the "Needles" —irregular pinnacles of erosion near the Colorado River—have been carved.

Southeastern Arizona ranges.—Satisfactory generalizations concerning the many mountain ranges of central and southern Arizona are difficult to make. These mountains have in common a general north-south or north-west-southeast trend and most of them rise abruptly to considerable altitudes from the low, flat, alluvial plains of the desert. A majority are composed chiefly of sedimentary strata that are steeply tilted, but there are notable exceptions. The Santa Catalinas, as exposed today, are mostly metamorphic. The Galiuro and some others are largely volcanic.

Each separate mountain range has a distinct and, in most cases, complicated structural history. Some involve folding, and some have their fronts raised along huge normal faults. Cross faults may or may not be present, and overthrusts are responsible for some of the ranges. In brief, a description of these ranges, adequate to illustrate the origin of each, would require a series of individual treatments and, in many instances, sufficient information is not yet available.

The more prominent of the mountains in this region are the Pinal, Mescal, Dripping Springs, Apache, Santa Catalina, Santa Rita, Wetstone, and Huachuca. Mining operations are, or have been, active in a majority of these. Other types of development are negligible except in the foothills and most development is handicapped by the general lack of permanent water.

Of the more prominent scenic attractions are such high peaks as Mount Graham (10,100 feet), Mount Turnbull (7,800 feet), Mount Lemmon (9,500 feet), and Baboquivari (7,500 feet). Also of note are the great steepwalled canyon of the Gila River (2,200 feet) in the Mescal Mountains and the weird monuments of erosion at Chiricahua National Monument. Several caverns, including Colossal Cave and Onyx Cave, are known, but none of outstanding character.

Southwestern Arizona ranges.—In the southwestern portion of Arizona is found the driest, hottest part of the State. The nearly parallel desert ranges that slant diagonally across this area from the northwest to southeast differ from those to the north in their orientation and from those to the east in being smaller and less covered with vegetation. Furthermore, they are almost entirely lacking in sedimentary rocks such as occur in the adjoining regions.

Mountain ranges in this region are of two principal types—those composed dominantly of ancient granites and schists, and those of relatively recent volcanics. Because these two varieties of rock weather very differently, mountains developed from each have distinctive shape and topographic expression. On the other hand, some ranges are combinations of both types of rock, with volcanic materials partially covering and concealing the older granites. In such cases, the resulting mountain types have mixed characteristics.

In the extreme southwestern part of this area the mountains are almost all of the granitic type. They include the Tinajas Altas, the Gila Mountains, the Cabeza Prieta, Mohawk, and Sierra Pintas. All are low and characteristically weather into blocks. In the northeastern part of the area other ranges, especially the Sierra Estrella and the Maricopa, are also of this type. Elsewhere volcanic rocks predominate and tend to make the ranges rougher and more impressive. Especially rugged and massive are the Kofa Mountains, northeast of Yuma, which rise with a sheer western front high above the alluvial plain at their base and which have several narrow, spectacular gorges cut into them, including Palm Canyon. Other smaller mountains of the group are the Castle Dome and Plomosa in the west and Growler and Sand Tank farther east.

The Whipple Mountains on the California side of Lake Havasu just to the northwest of Parker Dam are scenically spectacular because of their brilliant coloring, picturesque canyons and peaks of deeply eroded volcanic rocks, and the striking desert vegetation.

The Eagle Tail Mountains in the north central part of this area form a narrow, prominent ridge that is remarkable because of its picturesque peaks known as Eagle Tail and Court House Rock. These mountains are formed of a fine succession of early volcanic rocks.

One of the most interesting geologic features of this region is the Pinacate lava field at the international boundary southeast of Yuma. It is part of a very large area of volcanism extending southward into Mexico and is significant because of its recency. Lava is 50 to 100 feet thick with well-defined margins. Many small craters are present, all of them apparently very young. Through this rough but awe-inspiring terrain the famous Camino del Diablo passes.

Colorado Delta and Salton Sink.—The delta of the Colorado River is formed in, and controlled by, one of the most remarkable structural troughs on the earth's surface. It is a depression resulting from the subsidence of a long narrow crustal block between faults or breaks, comparable to the trough of the Dead Sea and Jordan Valley in Palestine. Extending for more than one hundred miles in a north-south direction, it is submerged at one end beneath the Gulf of California and is occupied at the other by the Salton Basin which is partly below sea level. In the central part, where the Colorado has for ages been piling up its load of sediment, the history has been that of the constructional activities of the river versus the downsinking of the trough.

Although much of the Colorado delta is in Mexico and therefore beyond the scope of this report, its effect on that part of California within the Salton Basin has been profound. There is evidence to indicate that despite recent subsidence, concurrent building of the delta has successfully kept the upper end of the trough blocked off from the Gulf of California. As a result, the Salton Sea is about 250 feet below sea level and has a depth of 24 feet, yet the river delta is built up to slightly above sea level.

Numerous features of unusual geologic interest are found in this area, but there is some question as to what extent they may be developed for educational or other purposes because of the inhospitable character of much of the delta area. Mud volcanoes occur on the west side of Volcano Lake in Mexico, and hot springs issue forth along the San Jacinto fault. At Travertine Point, a spur from the Santa Rosa Mountains that projects toward the Salton Sink from the west shore, are seen evidences of

former levels of the lake. North of the delta and west of Yuma is an extensive area of large, well-developed sand dunes.

PLAN RECOMMENDED FOR DEVELOPMENT OF CERTAIN RECREATIONAL FEATURES IN THE PLATEAU PROVINCE

In writing of the remarkable scenic features of the Colorado Plateau, Capt. C. E. Dutton stated in 1884: "Great innovations, whether in art or literature, in science or in nature, seldom take the world by storm. They must be understood before they can be estimated, and must be cultivated before they can be understood." This penetrating analysis of the problem that is faced in obtaining maximum recreational value from a region of exceptional and unique scenic character is the basis of a plan that follows.

Information available to visitors in the plateau region should not be confined to unrelated ideas concerning the immensity, the beauty, or the marks of erosion presented by such spectacles as Zion, Bryce Canyon, Rainbow Bridge, or Grand Canyon. Such features are truly great and inspiring, and normally have a profound influence on the thinking of those who see them, but as a source of mental stimulation they are surpassed in greatness by the history of the earth which is illustrated through them. To one who has not studied the geological processes this history will not at once be apparent, but with a very little explanation it may become understandable to any person of normal intelligence and will thereafter remain a source of great pleasure and inspiration.

Earth history as represented in the Colorado Plateau is not significant merely because of the chronological record that it represents, but also because it serves as a means of conveying certain great concepts to the human mind. These include the magnitude of geologic time, the reality of crustal movements and mountain uplifts, the evolution of life, and the never-ending processes of deposition, erosion, and volcanism. Such concepts are responsible for great mental stimulation and lead, through thought, to attainment of one of the highest forms of recreational enjoyment.

Events representing the history of the earth undoubtedly are more closely and simply illustrated by the record of the rocks in the Colorado Plateau than anywhere else in the world. In order that this history be skillfully and artfully presented to visitors of this region, emphasis must be placed on original materials. Facts must be dealt with and presented in a way that will guide people's thoughts toward a realization of the principles. By way of illustration, consider the result of calling attention to sea shells and corals in rock layers now some thousands of feet above the sea. In most cases, a concept of crustal movement and uplift will come to the visitor, evolved through his own thinking and not because of a theory advanced to him by some scientist. The thrill and satisfaction of discovery will be his.

From the preceding analysis it appears that the task of the planner is, first, to lead people to the best possible illustrations through a skillful development of roads and trails and, second, to make available, without forcing upon them, data necessary to a correct interpretation and correlation of facts. In the Colorado Plateau the normal flat-lying attitude of the rock layers and the orderly succession of beds according to age greatly simplify this problem.

There are three principal routes used today by visitors crossing the plateau region and, fortunately, each of these routes offers opportunity for seeing evidence of the normal succession of events in geologic history. One of the routes is from Grand Canyon northward, through Zion and Bryce. Another (which probably will be much used in the future) is from Grand Canyon northeastward through Tuba City, Kayenta, and Monument Valley. The third is from Grand Canyon eastward by way of Petrified Forest and Gallup. Visitors traveling any of these routes from Grand Canyon will pass through rocks from oldest to youngest or, taking the routes in reverse order, will start with the youngest layers and end with the oldest. Thus a unified story may be obtained and the history made appealing if it is properly explained along the route by wayside observation stations, markers for exhibits-in-place, and literature covering the routes.

It is clear that at each place of interest and significance along any of the main routes of travel not

only the local features of geology, such as fossils or rock structures, should be brought to notice as they appear in natural position, but also their place in the general scheme of things should be emphasized. This must be done primarily by means of charts and diagrams. Details of museum and exhibit development, of roadside signs, and of circulars needed to take people from one unit to another over these routes should be so planned as to have an orderly and appealing sequence.

Plant and Animal Life

RECREATIONAL VALUE OF PLANTS AND ANIMALS

Plants.—Regions devoid of plant life are among the most uninhabitable wastelands in the world. The rains or melting snows, unchecked by an absorbent mantle of forest or grassland, sweep over the bare slopes in torrents, carving out gullies that grow with the years until they become great barren valleys. Then, with the passing of each unchecked flood, the watercourses shrink to a trickle or vanish entirely.

Without plants there can be no cool, clear trout streams; no shady camping spots; no fertile, humus-bearing soil; no food for other forms of life. Even in desert lands there is usually a thin mantle of plant cover which, though sparse, helps hold the soil in place and permits a foothold for higher forms of life.

Recreational enjoyment of plants ranges from subconscious appreciation of their beauty and shade to active interest and wonderment at the marvelous diversity of plant forms which results from their adaptation to the earth's extremes of climate and environment.

Unity of plants and animals.—Plants and animals are dependent upon one another in a manner so complex and far reaching that they cannot be fully enjoyed, or protected, separately.

As an example of this interdependence, in mountain regions acorns roll downhill when they fall from the trees. Therefore, in the course of centuries the forests would travel downward from the high country and eventually would disappear if their reproduction were not assisted by other members of the plant-animal community. However, jays, woodpeckers, squirrels and other small animals that eat acorns assist the forest through their habit of carrying off and storing the surplus crop of nuts. Often these creatures fly or run *up* hill with the seeds, and not infrequently they fail to find them or are caught by some natural enemy before the storehouse can be used. Seeds which sprout from these abandoned supplies become the trees which maintain the forest in the high places.[1]

Figure 28.—Abert squirrel of the Transition Zone.

In a like manner, many species of desert yucca are wholly dependent for their pollination upon a single kind of moth. This insect thrusts its eggs into the plant tissues surrounding the future seed, where the larvae will be safe from most enemies, and at the same time collects and applies the yucca pollen by means of mouth parts that are specially shaped for this work.[2]

A commonplace, though very important and often forgotten, example of plant-animal dependence is the plowing and cultivation of the soil by billions of insects, earthworms, field mice, pocket gophers, moles, and other small burrowing animals. The vegetable matter that they drag underground to line their nests, or to eat, is transformed into

[1] Grinnel, 1936, p. 82.
[2] Holland, 1920, p. 441.

humus that is essential to plant growth. In addition, the loosening and turning over of the earth through burrow excavations permits air to enter, which is required by the humus-forming bacteria. It also allows water to penetrate the soil, which otherwise would settle and pack year by year until it became as impervious as sandstone. When water *penetrates* the earth instead of quickly running off the surface, there is far greater plant growth; the soil washes away but little or not at all; floods are fewer; the soil is more fertile; and the land is a better place for living—and for recreation.

Animals.—If plants are essential not only to other forms of life, but to most recreation, animals are hardly less so.

During the decade ending in 1930, hunters and fishermen increased 400 percent and totaled 13 million. It was estimated that the recreational attraction of wildlife accounted for 254 million dollars of tourist expenditures annually, and that 158 million dollars was spent by hunters.[3]

By 1945, in spite of wartime restrictions, 20 million anglers and hunters spent 2 billion dollars per year in pursuit of their sport.[4]

The postwar trend toward shorter working hours and increased leisure no doubt will result in still more hunting and fishing. Some estimates place the future annual expenditures for this purpose at 3 billion dollars.[5]

[3] Bureau of Biological Survey, 1935, p. 1.
[4] Carhart, 1945; cf. Presnall, 1945a, p. 18.

Figure 29.—Chipmunk of the Transition Zone.

Figure 30.—The spreading ripple of a beaver.

At the beginning of the war only about 2 percent of the millions who went into the armed forces had previous experience with firearms. Their new skill and acquired habits of wide travel surely will further stimulate hunting, and no doubt fishing as well.

The trend may be still further accelerated if there should be a revolutionary increase in civilian aviation, permitting the average sportman to reach even the remote and choicest fishing and big game areas in a few hours.

Fishing and hunting are only two of many recreational values of wildlife. Rivaling the sportsmen in enthusiasm is a rapidly increasing group of amateur and semiprofessional wildlife photographers. Though the hunter may have a lifetime of unforgettable experiences, the wildlife photographer can claim an even richer field of opportunity and golden memories. For him there is no closed season, and no animal, however rare, is on his forbidden list. With luck and patience he may "catch and hold," to enjoy forever, yet unharmed, many beautiful and vanishing creatures denied to the hunter, such as the trumpeter swan of the

[5] Carhart, 1945.

northern lakes or the stately bighorn of the crags and canyon walls.

Probably even more important, though less vocal than these special groups of enthusiasts, are the millions of persons who derive lasting enjoyment from just watching and being near wildlife. For them the splash and spreading ripple of a beaver on a twilit pond or the fairy-like chimes of a thrush in the cathedral stillness of a forest, are a source of inspiration complete in itself. Their enjoyment is not to be measured in dollars, any more than sunshine or freedom can be so measured.

STATUS OF PLANT AND ANIMAL LIFE

Original conditions.—The stories that early explorers brought back from the western wilderness of the incredible lushness and wealth of vegetation and wildlife read like fairy tales to us now, who will never see birds in flocks of millions that darken the earth for hours as they pass, or grass as tall as a man's shoulder, thronged with endless herds of buffalo, extending to the horizon. Civilization has left for present generations so little trace of the overwhelming primeval abundance of the "wild west" that the imagination, even when aided by the early records, now finds it almost impossible to reconstruct the original picture.

Because of the arid climate, the lowlands of the Colorado River Basin had a much less luxuriant vegetation than that of other regions in the West, such as the prairies and great plains on the east side of the Rockies. Nevertheless, by contrast with conditions in much of the basin today, the forage and the wildlife that it sustained were almost unbelievably abundant.

The vast sage plains of the Upper Green River Valley and the Red Desert in Wyoming were comparatively poorly stocked with game even in the early days[6] because of the scanty rainfall and the absence of water over large areas. Nevertheless, prior to 1850 there appears to have been considerable grass among the sage. Bands of antelope and buffalo roamed those regions where there was water[7] and sage hens came to the waterholes at evening by the thousands.[8] Elk in vast numbers wintered in the Red Desert. Now hundreds of thousands of domestic sheep use the region as winter pasture.[9] The buffalo have vanished, as has most of the grass, and the antelope and sage hens are but a small percent of their former numbers.

In the somewhat better-watered though still relatively barren sagebrush valleys of the Duchesne, White, and Yampa Rivers in northeastern Utah and adjacent Colorado there was good grass in 1844,[10] especially at the higher levels, and this condition lasted until about 1879. Buffalo were present, together with antelope[11] which sometimes were sold by the wagonload for meat. There were sage hens[12] and mountain plover in uncounted thousands, but, as elsewhere, these vanished at an early date. The upland plover, the existence of which now is threatened almost everywhere,[13] was "rather common" in 1877.[14] By 1892 the sharp-tailed grouse, once abundant, was rapidly disappearing as a result of overgrazing and burning.[15]

Even some parts of the Canyon Lands of Utah, now notable for the barrenness of their immense sandstone wastes, once were surprisingly fertile. Although cattle were abundant in the area by 1872, the Henry Mountains still stood in a valley of grass.[16] Antelope were seen frequently on the nearby San Rafael Swell[17] as late as 1895 by the few persons who penetrated this wild region, although these animals disappeared not long thereafter. Antelope Valley, which is southwest of the San Rafael Swell, undoubtedly got its name from the former presence of this species.

The great valley of the Little Colorado River now is covered with a sparse, scrubby vegetation composed principally of semidesert shrubs with bare soil and desert pavement between the scattered plants. Although some areas may always have been barren, in 1857 grama grass on great areas of mesa land grew tall and rank between these shrubs.[18] Elk, deer, and beaver were common in the valley

[6] Dale, 1918, p. 150.
[7] Seton, III, 1929.
[8] Bendire, 1892, p. 111.
[9] Cary, 1917, p. 21.
[10] Fremont, 1845, p. 278.
[11] Cary, 1911, p. 58; Powell, 1875, p. 40.
[12] Twomey, 1942, p. 387.
[13] Beard *et al*, 1942, p. 259.
[14] Twomey, 1942, p. 391.
[15] Bendire, 1892, p. 101; Utah State Fish and Game Commission, 1940; p. 24.
[16] Thompson, 1939, p. 87.
[17] Barnes, 1927, p. 171.
[18] Thornthwaite, *et al*, 1942, p. 65.

near Winslow and on the adjacent grassy plateaus, and there were great herds of antelope.[19] Since 1852, herds of cattle and sheep have replaced the antelope bands, and the grass is abundant only at higher elevations in the basin where lack of water has prevented grazing by domestic stock.[20]

Even the vast, unpopulated southern desert lands which are commonly imagined as eternally unchanging would in many places hardly be recognizable to those who first discovered them. Many desert watercourses that present generations are accustomed to think of as dry washes, or as intermittent streams at most, once flowed the year round. The more luxuriant desert vegetation of those early days checked the run-off from the storms more efficiently than at present, thereby reducing the volume of flash floods and distributing the stream flow more uniformly throughout the year.

Those who are familiar with the bare, dry, sandy bed of the present intermittent Santa Cruz River at Tucson, in the heart of the Arizona Desert, will find it difficult to believe that prior to 1776 water there was so abundant that travelers sometimes had to wait for 6 weeks before it was possible to get horses across its swampy expanse. During the latter part of the eighteenth century the Spanish inhabitants of southern Arizona could ford the San Pedro and other rivers only at certain places.[21] Tucson was established at the site of the swamp on the Santa Cruz River because of the abundance of wood, water, and meadowland at that time. Where now there is only powder-dry desert, the grass once reached as high as the head of a man on horseback.[22] The river bottom then was densely forested with giant mesquites that formed a wide green belt extending down the valley for many miles. The region teemed with immense numbers of quail and doves. Peccaries and other wildlife of Mexican origin were abundant and beaver were plentiful.

After 1800, the valley was denuded of its mesquite forests, and the ironwood was stripped from the hills to feed the nearby lime kilns and provide fence posts. The beaver were trapped out and their dams destroyed. With the disappearance of the vegetation, the wildlife that depended on it also vanished. This history has been repeated in various degrees in the San Simon (once lush with grassy meadows), the San Pedro, and nearly every other mesquite valley of the Southwest.

Changes in the desert away from the river bottoms have been equally profound. Today we are accustomed to desert lands in which there is little or nothing between the widely spaced cacti and woody desert shrubs except rocks, gravel, or bare sand. However, before 1870, the spaces between the desert shrubs were quite generally filled with grama grasses,[23] and it was these highly nutritious grasses that maintained the herds of antelope that were common in those days.

After 1870, cattle increased greatly in the desert regions and the grama grasses thinned and disappeared. The trampling hoofs stripped the thin protecting layer of decaying plant materials from the surface of the soil, which then dried up, and gradually blew away, or was washed away by unchecked flood waters, leaving the bare gravel and sand that we know as "desert pavement." When the cattle removed most of the grass, the cacti and tough, unpalatable shrubs were able to multiply and predominate as they had not before.

Not only were the antelope starved out, but in some regions the character of the desert vegetation itself slowly changed. Seedlings of the giant saguaro of southern Arizona require moisture-holding duff and the protecting shade of dense, low-growing brush in order to establish themselves. Over great areas of the desert these necessary conditions were removed many years ago by the grazing of cattle and have never been restored.[24] The old saguaros that lend to the Arizona Desert much of its spectacular charm now stand on practically bare soil. They are commencing to die of old age, and with their disappearance will come a great change in the landscape and far-reaching reverberations among the desert birds and lesser wild creatures that depend upon the saguaros for their existence.

The new generation to replace the dying saguaro forests is sparse or lacking. Restoration of soil, decaying plant materials, and humus would require many years even if commenced at once. A saguaro seedling requires 10 to 15 years to grow to a noticeable size and 20 to 30 years to reach above the

[19] Nichol, 1937, p. 197; Knipe, 1944, p. 22.
[20] Hanson, 1924, p. 20.
[21] Thomas, 1941, p. 149.
[22] Carr, 1945, p. 366.
[23] Dodge, 1945, p. 6; Darrow, 1944, p. 360.
[24] Dodge, 1945.

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surrounding shrubbery. Thus the desert could hardly reverse its present trend within the next 50 years even if actually encouraged.

The fading picture of primeval beauty and abundance has not been confined to the valleys and deserts. The vegetation of the mountains originally was much more luxuriant and its resistance to grazing was greater, because the more abundant rainfall gave it greater vigor. However, the process of deterioration has been the same, although it has taken a little longer. In 1847, grass in some canyons of the Wasatch Mountains in Utah was from 6 to 12 feet high, and in some places the first explorers found themselves unable to penetrate the thickets which it formed. Today, the grass in these places often is less than 6 to 12 *inches* high, offering no obstacle to travel in any direction. Great numbers of unpalatable weeds and shrubs have replaced the original forage, of which many of the best kinds are on the verge of extinction.[25]

In 1844, Mountain Meadows, on the summit of the Colorado River–Great Basin divide in southwestern Utah, was a beautiful valley of green grass that extended for miles, bounded by piñon- and juniper-covered hills. By 1877, the grass had been mostly replaced by desert shrubs as a result of sheep grazing, and the appearance of the landscape was so greatly altered that landmarks of 20 years before could no longer be identified. Today the "meadow" is dry, and gray with sage. Great gullies have drained away the water, so that even if ungrazed, the grass could not come back. Junipers have been steadily invading the site of the vanished meadow from the surrounding hills since 1862.[26] These conditions are fairly typical of changes which have occured throughout the mountains of the Colorado River Basin.

Animal life in the mountains has undergone a corresponding decrease, as a result of direct persecution, as well as from forage and habitat depletion. In primitive times, elk were abundant in nearly all the mountains and foothill valleys of Wyoming, Colorado, northeast Utah, central New Mexico, and northern Arizona as far west as the Hualpai Indian Reservation.

> A very trustworthy observer who has lived in the Ashfork region since 1896, says there was one old Merriam bull elk that watered with the cattle north of Ashfork as late as 1914. I could never question his record as he is a most conservative and careful reporter. He gave me a pair of Merriam horns a few years ago, one of two pair which he picked up in this same general area several years ago.[27]

By 1910, they were nearly exterminated in the Colorado River Basin, but subsequently, determined efforts, particularly in Colorado, have restored them to part of their former range.

When the first white settlers came, bighorn in great numbers seem to have occupied nearly every canyon, cliff, and mountain range of the Colorado River Basin, but they began to decline about 1840.[28] By 1900, hunting, competition with domestic stock for the diminishing forage and water, changes in the type of forage plants, and diseases introduced by the domestic herds had reduced the bighorn to a dwindling fraction of their original numbers.

Beaver, which had molded American history for a century in the well-watered lands to the east and north, were remarkably abundant even in the Colorado River Basin in primitive times. In 1825,

[25] Cottam and Evans, 1945, p. 178.

Figure 31.—Desert bighorn in Lake Mead Recreational Area.

[26] Cottam and Stewart, 1940, p. 624.

[27] A. A. Nichol, letter, Dec. 29, 1945.

[28] Seton, 1929, III, p. 532.

James O. Pattie caught 250 beaver in 2 weeks on the San Francisco River of Arizona and New Mexico.[29] The San Francisco is a tributary of the Gila River, which has but a meager stream flow today. Other trappers, including the famous Bill Williams, also found beaver abundant along the Gila and Salt Rivers.

Although beaver trappers had little success in the desolate gorges of the Colorado River in southern Utah, they found thousands of the animals in the more hospitable headwaters of the Green and Colorado Rivers. Individual trappers in the Rocky Mountains sometimes took as many as 500 beaver per year. However, the beaver's fate was like that of the buffalo, antelope, elk, bighorn, sage hen, turkey, grouse, and waterfowl. Though their original numbers had been immense, and though for untold thousands of years they had flourished in the presence of their natural enemies, the so-called predators, yet against the attacks of civilized man they held out less than 25 years before being brought to virtual or complete extinction. By 1840, the beaver market went into a decline from which it never recovered. Recent conservation measures have brought about good recovery in some areas, but the profound changes in the land brought about by human settlement and development make it impossible for the animals ever to regain their primitive numbers.

Almost as much a symbol of the wilderness of long ago as the buffalo is the wild turkey. In 1824, there were thousands of them in practically all the forested mountains and foothills of Arizona, New Mexico,[30] and southern Colorado (as well as in similar areas adjacent to the Colorado River Basin). In Arizona, they even came down from the mountains to the banks of the San Pedro River, which was thickly overgrown with giant mesquites at that time, and ventured into the desert far enough to feed on the fruits of the saguaro.[31] Wild turkeys now seldom wander from the ponderosa pine forests of the Transition Zone, and even in that zone they have been reduced to a fraction of their original numbers. In Texas, it has been shown that overgrazing eliminates many food plants required by wild turkeys.[32]

[29] Seton, 1929, IV, p. 448.
[30] Bailey, 1928, p. 231; Bendire, 1892, p. 116.
[31] Bendire, 1892, p. 119.
[32] Taylor, 1944, p. 234.

The chronicle of disappearance and deterioration throughout the Colorado River Basin since 1825 would be long if given in full, *although the region has lost less of its primitive resources than have many other parts of the United States.* To gloss over these great losses of the past would be futile, for the forces that brought about many of them continue almost unchecked even today. The only hope lies in recognizing them, in learning their causes, and in actively working to stop them *now.* An account of some of these causes follows, with an indication of remedial measures.

Changes caused by man.—1. Farming. A fertile environment produces large numbers of plants and animals, but an infertile one can support few or none. This fundamental biological rule governs practically all living creatures, including man. It goes far toward explaining the widespread disappearance of wildlife following human occupation of the country.

The plains, foothills, and lower valleys—not the cold mountains or the rainless deserts—have a virtual monopoly on the moisture, warmth, and deep, fertile soils that are necessary to produce abundant vegetation and other raw materials required by the higher forms of life. An abundant vegetation is required to feed the billions of insects, worms, and other invertebrate creatures that support the hordes of small birds and rodents. These, in turn, make possible the existence of such valuable fur bearers as the raccoon, marten, and the rare fisher, and the picturesque hawks and eagles which act as a "gov-

Figure 32.—Mule deer.

ernor" to prevent the overproduction of the herbivorous animals.

An abundant vegetation is required also to sustain the deer, elk and antelope, beaver, wild turkey, grouse, and waterfowl that once swarmed over the plains and foothills in such numbers that they were thought to be inexhaustible. The same biological relationship between warmth, abundant food, and large numbers of animals enables the more fertile waters of the lowlands to support many more fish than can the waters of the mountains, and permits the individual fish to grow larger.

Although excessive fishing and the slaughter of game on a commercial scale were among the principal causes of wildlife depletion at the time that the country was settled, several more deep-seated causes soon commenced to operate and have continued to hasten disappearance of the original conditions long after the wholesale slaughter of the early days was halted by law. One of these causes of depletion has been the occupancy of most of the choice, fertile regions of the country by cities and farms.

Elk, deer, beaver, turkeys, and many other wild creatures, that in the West are considered today to be almost exclusively mountain dwellers, had their centers of abundance, particularly during the winter, in the lower hills and adjacent valleys. When these lowlands were cleared for farming or for the establishment of cities, the original plant-cover was destroyed and the animal life was forced to move, if it could. The elk and deer which previously had used the mountains primarily for summer range now were forced to live there the year round. Other less adaptable kinds of animals dwindled away or died out completely.

Retreat into the mountains, however, brought new problems of existence for those animals that were able to change their life habits in this manner. Fur-bearing animals found fewer rabbits, mice, and birds because the growing season for vegetation required by the latter was shorter at the higher altitudes. The deep, long-lasting snows often buried more than half of what browse there was beyond reach of elk and deer. Many mountain lakes used by waterfowl in summer froze solid in the winter months. The biological relations between numbers of animals and fertility of the environment immediately operated to maintain the migrants from the lowlands at a permanently low population. Competition between different kinds of animals for what little food there was became unnaturally severe during the winter months. Elk crowded into what was formerly a sheltered range of bighorn in the ponderosa pine belt, thereby forcing the bighorn to remain all winter on the higher, windswept areas above the timber line.[33] Today, the cold mountains and the rainless deserts are the principal remaining strongholds for many kinds of wildlife, not because they are the most suitable or productive areas, but because they are all that man has left in a relatively undisturbed condition.

However, wildlife has dwindled away in the desert, too, for settlements have been built around some of the best watering places. Water from many of the remaining scattered springs has been piped away to mines and ranches, and, as mentioned later, even the rivers have dried up. Where water still remains, it is often used so heavily by livestock that all vegetation in the immediate vicinity is destroyed, leaving no cover for game birds or other animals. Under such conditions the water is as unavailable as though it had been fenced or piped away.

2. Grazing. In the days of early settlement, grazing was carried on with the same reckless, competitive abandon as was the first cutting of timber and the commercial slaughter of wildlife for the meat market. No natural resource, however abundant in the beginning, has long withstood such wasteful use.

At the termination of the Civil War in 1865, the cattle business of the West entered a boom period comparable to the Gold Rush. In the scramble to get rich from the vast, new, unfenced lands, great syndicates were formed in the East and in England, and men and money poured in even from such faraway places as Australia.

North and west from the Great Plains through the Uinta Basin in Utah and the Red Desert and the Upper Green River Valley in Wyoming, all the way to Canada, the tide rolled in. So abundant was the grass at first, even in that inhospitable climate, that no winter feeding was done—an inconceivable practice today. With such overstocking the primitive grassland disappeared. The severe winter of 1886 brought about the end of boom times. Cattle perished by the thousands, and unlimited grazing

[33] Ratcliff and Sumner, 1945, p. 246.

without winter feeding in the Northwest States collapsed. By 1895, "not an acre of grazing land was left unoccupied, and ranges that for permanent and regular use would have been fully stocked with a cow to every 40 acres were loaded until they were carrying 1 to every 10 acres."[34]

In the Southwest the story was repeated a few years later. Grass grew more slowly than in northern regions because of the lighter rainfall. Although often luxuriant, the grass withstood the reckless grazing competition less easily because its moisture requirements were close to the danger line of water availability. Mountains and plains, stripped of their green covering, turned to dust. Freshets tore away the trampled sod of mountain meadows and cut deep gullies into the unprotected soil, thereby draining the meadows and turning them into deserts. In 1893, drought and ruination of the range brought the cattle boom of the Southwest crashing to a finish.[35]

The forage of the early days, like the wildlife, never has regained its primitive abundance. Perhaps it never will, even with the application of conservation measures learned in later years, for when the forage commenced to die from overuse, the soil began to die, too. Just as animals and plants are dependent upon one another for life, so are plants and the soil mutually dependent, both for their daily existence and their perpetual renewal.

Importance of topsoil.—Topsoil, the life substance of grass, is a porous, chemically active medium, sometimes one-third to one-half air and from a tenth to one-fourth water.[36] In the surface layers of good topsoil, the air, the water, and the warmth of the sun combine to form a rich culture medium for a vast unseen world of struggling micro-organisms—billions of them to the square foot. Bacteria, protozoa, and microscopic fungi, during their own life processes, change the free nitrogen of the soil, and the nitrogen of decaying materials, into substances that plant roots can assimilate. By their endless rotting and disintegrating action on rocks and dead roots, on the bodies of other animals and last year's half-buried leaves, they keep the spaces between the soil particles open, whereby air, water, and warmth keep the fermentation process going on endlessly.

The microscopic soil-makers are aided by the millions of tiny worms and burrowing insect larvae that drag living and decayed vegetation, which they use for food, beneath the surface where the bacteria, too, can reach it. This yeasty brew of invisible, silently struggling creatures is a thin web of life draped over the mountains and valleys of the earth wherever there is topsoil. The chemicals which it distills are the life-juices that the roots of the plants must suck from the soil in order to live. Without topsoil, life for most plants is impossible.

However, topsoil seldom is more than 7 to 12 inches deep.[37] The chemical processes that form it, through the gradual decay of underlying rock, and the mixing of this rock with the products of organic decay derived from the surface of the soil above, are very leisurely. Some rich soils may accumulate at the rate of not more than 1 inch per 1,000 years.[38] Therefore, if a 7-inch layer of such a topsoil is removed, the full thickness cannot be replaced from the barren, chemically inert stratum of disintegrating rock beneath it in less than 7,000 years, even if all other conditions should be favorable for the required reaction.

Thus, when all of the topsoil is removed, the land dies, and with it die also the plants and the animals, whose lives are all so inextricably bound up together.

Difference between natural and man-caused erosion.—Removal of the soil layers, by whatever means, is known as *soil erosion*. We are concerned with it in the Colorado River Basin because much of this soil erosion was caused by ruinous overgrazing in the early days of settlement. But first a frequent and dangerous misconception must be corrected regarding two very different kinds of erosion, and man's responsibility in relation to them.

Natural or geologic soil erosion is a slow process, except in a few special areas. It is so slow that in humid climates, where the soil is held together by a luxuriant protective mantle of forest and grassland, the rate of new topsoil formation balances the rate of erosion. Even in an arid climate like that which prevails in most of the Colorado River Basin

[34] Barnes, 1926.
[35] Lord, 1938, p. 66.
[36] Lord, 1938, p. 1.
[37] Bennett, 1941, p. 1.
[38] Lord, 1938, p. 7.

away from the mountains, the accumulation of vegetable litter, the formation of new soil, and the healthy growth of a protective covering of grass originally occurred on almost all slopes and flats. It is true that in the Colorado River Basin the lowering of stream beds and canyon bottoms by natural erosion, and the reduction in size of plateaus and buttes by the weathering and collapse of their vertical-walled perimeters, proceeded at a rate that, geologically speaking, was fairly rapid, when compared with that of some other regions. The top surface of the country also was extensively planed down during the lapse of millions of years. Nevertheless, in terms of year-to-year continuity, the topsoil was healthy, and maintained a wealth of plant cover and animal life in startling contrast to what is found today. *Natural* erosion originally was no insuperable obstacle to fertility and abundance even in the desert. For example, in the great expanse of sandstone soils of the Little Colorado River Basin, "where the cover of grass, sage, and other low growth has not been disturbed by grazing, erosion is of no importance; but under conditions of depleted vegetation, as a result of overgrazing, sheet erosion, gullying, and wind erosion are active over large areas."[39] The soil has sickened and commenced to die only after the balance has been disturbed by the coming of the white man.

Man-caused or "accelerated erosion" results when grazing and other agricultural activities strip away the plant cover and allow the wind and water to wear away the topsoil more rapidly than nature ever did. In many places, this living surface layer, product of hundreds of centuries of microscopic accumulation, has completely disappeared, and the land has died within the space of 20 years.[40] The misconception of those who fail to distinguish between natural and man-caused erosion, imagining that the consequences of the latter are of little importance, is like that of a person who would ignore the fact that his house had caught fire, on the theory that fire always had existed as a purely natural phenomenon.

Franklin Flat, in the San Simon Valley of Arizona, was covered with grassy, flower-spangled meadows in 1882. Grass was stirrup-high along the continuously flowing river, which had practically no banks. In 1895, 50,000 cattle were grazing in the valley. By 1934, as a result of overgrazing, the green meadow cover had been replaced by drifting sand and the river, now an intermittent stream, had cut a chasm through the heart of that once-fertile land.[41]

Oraibi Wash, once a small stream tributary to the Little Colorado River in Arizona, has been cut by silt-laden, runaway waters into a twisting gully 80 miles long and from 20 to 80 feet deep.[42] The adjacent Polacca Wash commenced to deepen after 1868, when immense numbers of livestock were crowded upon the newly created Navajo Reservation. Now the wash is dissected by a continuous 90-mile gully from 10 to 50 feet below the valley floor, with great tributary gullies that continually eat into the slopes of Black Mesa. Today, "overgrazing has altered the plant association on the mesa areas of the Polacca Wash drainage and has so increased the run-off that all rains except those of very low intensity cause soil erosion".[43] Most of the hundred-foot-deep channel in the Jadito Wash has been cut since 1914.

Chaco Canyon had no gully in 1849 and contained a continuous, clear stream. By 1877 an arroyo 16 feet deep and 40 to 60 feet wide had developed. In 1924 this arroyo was 30 feet deep and 200 to 300 feet wide. There is no stream there now except during flash flood.[44]

The Santa Cruz River did not develop a continuous channel until 1890.[45]

> Until about 1888, the (San Pedro) valley consisted of a narrow strip of very fertile subirrigated fields. Beaver dams retarded the flow and prevented channel cutting. Trapping of the beavers and removal of the grass from the hillsides allowed such an increase in erosion that by 1892 or 1893 a channel 3 to 20 feet deep had been cut almost the whole length of the river.[46]

In 1846, even the Gila River, which, like the Colorado River, receives much sediment from *natural* erosion, flowed clearer. Its tributaries commenced to erode rapidly only after 1870.

[39] Bennett, 1939, p. 794.
[40] Lord, 1938, p. 7.
[41] Lord, 1938, p. 112; Soil Conservation Service, 1935, p. 5.
[42] Lord, 1938, p. 109.
[43] Thornthwaite *et al*, 1942, p. 122.
[44] Thornthwaite *et al*, 1942, p. 103.
[45] Schwalen, 1942, p. 427.
[46] Thornthwaite *et al*, 1942, p. 103.

Kanab Creek, in southern Utah, commenced to erode severely in 1883. Three years later a gully 60 feet deep, 70 feet wide, and 15 miles long had been formed.[47] Formerly timbered slopes on the Chuska Mountains of northwestern New Mexico have been eroded down to bedrock in some places as a result of overgrazing.[48]

Wind has added its influence to that of water in scouring away the unprotected topsoil. Winds are strong over the Colorado River Basin, but in the early days of settlement, dust storms and whirlwinds were relatively small in scale and infrequent. Trampling hoofs loosened and broke the protective, all-embracing grip of the virgin grass roots. When the plant cover was depleted, the soil dried out and become pulverized. Now the whirling dust columns march across the desert and semi-arid lands of the basin during the spring, summer, and fall months. Finer soil particles are sucked high into the air and sometimes are carried hundreds of miles; coarser particles are rolled and skipped along the bare surface, accumulating in drifts when they encounter an obstacle. Dust storms last for days, particularly in the basin of the Little Colorado River, obscuring the horizon. When the wind blows continuously, "blow holes," where the soil is lighter or the vegetation scantier, send up such a stream of dust from a given spot that from a distance it resembles the billowing smoke of a factory.

> The great dust storm of May 12, 1934, stimulated national interest in the problem of erosion. This spectacular dust cloud was the first one in history big enough to retain its identity as it swept across the country from the Great Plains to beyond the Atlantic Coast. It blotted out the sun over a large part of the nation and sifted through the windows of New York skyscrapers. When that happened it began to dawn on the public that something had gone wrong with the land resources of the nation.[49]

Meaning of soil erosion to human welfare.—The seriousness of soil erosion to the future of the entire Nation has been emphasized over and over again by experts, who have ably presented the picture of slow destruction. The dying of the soil is all the more insidious because the first stages often have been slow enough to escape notice from one generation to another. By the time they have speeded up and become conspicuous, complete restoration is usually hopeless. The Soil Conservation Service estimates there are in the entire country some 200 million erosion gullies. These, and the still more widespread sheet-erosion, already have ruined 14 percent of the United States or an area nearly eight times as large as Wisconsin. An additional 35 percent of the land is now threatened.

These facts regarding soil erosion in the country at large help to give some perspective regarding conditions in the Colorado River Basin, where aridity accentuates the problem. In that region,

> . . . crops often are poor and pastures thin, not because of insufficient rainfall but because too much of the available rain is permitted to run to waste. In other words, although the actual climate is unchanged, the effective agricultural climate or effective rainfall in terms of water at the plant roots has been tending in many areas, under this artificial acceleration of runoff, toward the equivalent of a very dry climate. When this tendency is combined, as it generally is, with a continuing loss of fertility through erosion, the farmer faces a serious prospect of steadily declining yields and steadily dropping income.[50]

Obviously this prospect of decline applies also to other soil crops of the region, such as native plants and wildlife.

The Forest Service estimates that it takes one-fifth more range of the tall-grass type to feed a cow now than when the range was first used. On short-grass range, nearly twice as much acreage is needed now; on sagebrush-grass range, more than three times the original acreage; and on salt-desert shrub, three and one-half times the former amount. Continuous overgrazing has changed the whole character of the range, reducing the quantity and quality of the forage and deteriorating the soil itself.[51] The importance to human welfare in the Colorado River Basin of this reduction in the production capacity of range land may be judged from the fact that grazing outranks all other agricultural interests there manyfold.

Soil washed downstream from the uplands is de-

[47] Thornthwaite *et al*, 1942, p. 103.
[48] Bennett, 1939, p. 794.
[49] Bennett, 1939, p. viii.
[50] Bennett, 1941, p. 14.
[51] Lord, 1938, p. 67.

posited in lower-lying areas whenever the velocity of the water is decreased by a lessening of the stream gradient. In the Colorado River Basin, material that has been removed from other areas seldom benefits the land on which it is deposited, and usually does great damage. If erosion in the uplands has been going on very long, the sand, gravel, and inferior subsoil that is washed downstream covers the good bottom lands with a layer of inert materials.

Reservoirs become choked with this sand and gravel, and with a fine slimy mud that kills fish and spoils recreation. Often the deposited materials interfere so seriously with water storage as to threaten the principal purpose for which the reservoirs were constructed. In extreme cases, such as the removal of all watershed vegetation by fire, reservoirs have been almost completely filled with soil during a single month of heavy rain.

> In the Southwest high rates of silting are largely the result of overgrazing, which induces extraordinary sheet and gully erosion. At the Elephant Butte and Zuni Reservoirs in New Mexico and Coolidge and Roosevelt Reservoirs in Arizona, the watersheds are subject to both sheet and wind erosion and to arroyo and gully development and the badlands type of dissection. In the watershed areas of the Zuni and Roosevelt Reservoirs, sheep grazing under arid conditions which has reduced the vegetal covering is responsible for much of the accelerated erosion.[52]

When the retarding influences of vegetation and soil porosity are lost, floods increase in violence. There have always been floods, even under strictly natural conditions, but the nature and the enormous extent of recent deposits along thousands of streams are proof to geologists and soil surveyors that the floods of today have become increasingly violent and dangerous following the destruction of vegetation.[53]

Some stockmen, and a few others, while admitting that these profound land changes have indeed commenced since the advent of heavy grazing, maintain that there is no true connection between the two, and that the real cause of the range deterioration is to be found in a recent change of climate. This claim is not supported by recent careful investigations.[54]

> Examination of evidence in tree-rings, lake levels, cutting and filling of valleys, and in the development of pueblo peoples fails to reveal proof of any climatic change in the Southwest in the last 2,000 years. Climatic fluctuations of the magnitude experienced today have occurred, and intense storms and groups of intense storms have had their effect on the landscape, but if there has been any progressive change toward either a more humid or a more arid climate that trend is so slight as to be completely overshadowed by the shorter period fluctuations.[55]

Hunting, fishing, and trapping.—The pioneer days, marked by the careless, mass slaughter of wildlife—when millions of waterfowl glutted the meat markets, when antelope were hauled to town by the wagonload, and buffalo were shot by the thousands for their tongues alone, or for fun—are gone. Before the killing was stopped by belated conservation laws, some of the most incredibly abundant wildlife species had been nearly exterminated and several had vanished forever.

Nevertheless, as far as hunting and fishing are concerned, the picture today is no longer black. Conservation organizations have sprung up in great numbers, many of them organized by hunters and fishermen. Conservation of natural resources is taught in the schools, and many universities now offer comprehensive training in the field of wildlife management, which has become a recognized profession. State and Federal protective legislation has become more and more responsive to the demands of national conservation groups, and, in recent years, has begun to take into account the investigations and recommendations of trained biologists. Some threatened species already have been partially restored, or at least rescued from extinction.

Much progress in conservation education remains to be made, particularly in bringing about public and legislative recognition of the great value of many so-called "predators," the importance of which has been conclusively demonstrated by the comprehensive investigations of innumerable field

[52] Soil Conservation Service, 1935, p. 16.

[53] Lord, 1938, p. 13; Thornthwaite *et al*, 1942, p. 91.

[54] Stewart, Cottam, and Hutchings, 1940, pp. 289-292.

[55] Thornthwaite *et al*, 1942, p. 125; cf. also pp. 43-46, 123-216.

biologists. Even here, however, the trend is hopeful. Hunting, fishing, and trapping no longer are the principal obstacles to the restoration of wildlife. Land use, or abuse, in relation to the remaining soil and plant cover, will determine the destiny of our native plants and animal life.

Stream pollution.—Because of the sparse human population in the Colorado River Basin and the relative scarcity of large industrial establishments, stream pollution is not nearly as serious as in the East. However, mine and mill waste has destroyed large numbers of fish at times,[56] and still is responsible for the poor quality of fishing in many Rocky Mountain streams.

The recent introduction by man-caused erosion of great quantities of sediment into streams that formerly were clear is a form of pollution. Fish food is destroyed during floods when the moving sand and gravel tear aquatic plants and animals loose from stream beds and grind them to pieces. Silt deposited in stream and lake beds smothers aquatic growth in a manner comparable to the burying and killing of topsoil on land by the deposition of inert layers of flood-borne sediment. Fish may be killed directly when spawning beds are covered by the silt deposits and the eggs smothered. In severe floods the fish often are suffocated by the suspended mud or crushed by the moving masses of rock and gravel.[57]

Even in the absence of scouring floods, any fine silt or mine sediments that may be suspended in the water are extremely harmful because they shut out the sunlight that is required for the growth of bottom-dwelling aquatic plants. These plants, particularly the microscopic forms, are the starting link in the aquatic food chain in the same general way that topsoil organisms have been shown to be the starting link in the terrestrial food chain.

REMEDIAL MEASURES SO FAR TAKEN

The decline of wildlife reached an all-time low in the late 1920's. Since then, vigorous conservation efforts have partially restored some, but by no means all, species.

Regulations.—Gradual enactment of fish and game laws finally checked the old-time slaughter of wildlife, rescuing some species from the verge of extinction and permitting others to recover to a considerable extent. Such regulations were absolutely essential and always will be part of any conservation program, but they cannot solve the fundamental problem of wildlife production. They can be used to curtail the taking of wildlife to a safe proportion of the remaining numbers, but they cannot restore the worn-out land, de-silt the streams, or bring back the grass. If and when such a restoration is accomplished, present hunting and fishing regulations no doubt can be extensively liberalized.

Artificial propagation.—In recent years, large sums have been spent annually by State and Federal departments on artificial fish propagation. Similar expenditures are made by State and private agencies on the propagation of game birds, and by private industry on the production of fur bearers.

No doubt, artificial fish propagation always will be necessary to satisfy the requirements of the vast and growing number of fishermen. However, the addition of new fish, no matter how great the numbers, cannot restore the productivity of lakes and streams. If the former productivity and stability of the waters can be restored, artificial propagation either can be reduced or, if maintained at the present volume, can furnish vastly more recreation to still greater numbers of people.

The artificial propagation of game birds is becoming recognized as an expensive substitute for the process which nature formerly accomplished on an incomparably greater scale. A few introduced game species have been able to hold their own in an impoverished man-made environment, just as certain plant species have been able to take over after the native grasses were killed out. However, it has been learned that permanent results usually are dependent upon restoration of the land to something like its former productivity. When this is accomplished, nature needs only moderate help from man in restocking.

Fur farming is replacing wild trapping to an increasing degree because of the declining productivity of the wild lands. One of the benefits of restoring some types of lands, and using them on a

[56] Ellis, p. 127.
[57] Moffett, 1936.

sustained yield basis, will be the revenue from furs. However, if the current demand prevails, commercial fur farming hardly will lose its present importance.

Refuges.—The establishment of wildlife refuges has on the whole brought excellent results. Their necessity is indisputable, and the only questions that might be raised relate to whether present distribution is adequate in all parts of the country, and whether existing and potential refuges might be made more productive.

There seems little question that the present number of waterfowl winter refuges, in the United States as a whole, is insufficient to feed the number of birds now being produced during the summer months in Canada and Alaska.[58] In the Colorado River Basin, as elsewhere, former natural feeding grounds for waterfowl have been converted to agricultural use, thereby further aggravating the problem. Reservoir construction offers a potential solution to the waterfowl feeding problem, but such a solution remains strictly theoretical unless operating water levels in the reservoirs are kept within such bounds as to permit the actual production of food for waterfowl.

The States of the Colorado River Basin operate many important refuges for waterfowl and game animals, but within the actual limits of the basin the distribution of refuges is irregular. An increase in the number of refuges within the basin would be beneficial *provided* the productivity of the land also was restored. "Most wildlife refuges provide feed. Most refuges for mammals only protect them from shooting and do not exclude domestic stock. This difference is fundamental."[59] The present restricted status of antelope in northern Arizona, where the creation of antelope refuges would be inadvisable at present because of the lack of grass, is a good illustration of this point.[60]

The vast amount of Federal land in the Colorado River Basin would, if other circumstances were favorable, make possible the creation of a system of refuges of far-reaching importance. The Fish and Wildlife Service maintains a number of waterfowl refuges on various large reservoirs, and several important desert game refuges. Production of food for waterfowl on these reservoirs is small, and consequently their potential value is largely unrealized. As in the case of State refuges, extension of a Federal system of game refuges would be beneficial only if the productivity of the land were restored.

The National Park Service, by reason of its policy of maintaining absolute sanctuary for wildlife, maintains in effect an irregularly distributed system of refuges along various parts of the Colorado River. However, a fundamental defect of some national park and monument areas as wildlife refuges has been their relative lack of fertility. Rainless deserts and barren canyon walls often make spectacularly beautiful recreation areas, but as a rule they can produce only inconsequential numbers of wildlife.

The U. S. Forest Service administers some of the largest and most outstandingly productive natural habitats remaining in the Colorado River Basin. In contrast with the general situation throughout the remainder of the basin, most wildlife has held its own there in recent years, and some species have increased. One reason for the better status of wildlife in the national forests is that the latter are located principally in the foothill and mountain areas, which are the regions least subject to transformation by urbanization, heavy industry, and intensive farming. Another reason is that wildlife has received increasing consideration in forest management following recognition of its recreational value. The result is that forest lands function as one of the most important refuge systems in the basin, even though hunting is permitted. However, aside from the hunting, which is a legitimate form of recreation and is carefully regulated, national forests are by no means absolute wildlife sanctuaries. This is because under the existing principle of "multiple-use," other economic activities that interfere in varying degrees with maximum wildlife production are allowed to dominate. Heavy grazing, and the intensive trapping of rare fur bearers, probably are the most serious of these competing economic activities at present. In theory, the great body of knowledge that has been accumulated on game and range management shows the way to a profitable reconciliation that will also restore land productivity, but in practice, local pressure groups

[58] Salyer, 1945, p. 45.
[59] Bond, R. M., 1945, in letter.
[60] Knipe, 1944, pp. 10, 22, 38.

in many areas so far have prevented the actual application of the needed reforms to the land.

Soil conservation.—The Soil Conservation Service, of the U. S. Department of Agriculture, has been engaged since 1933 in large-scale demonstrations of how to prevent man-caused erosion and restore the soil to its original productivity. These demonstrations are given at the request of soil conservation districts, which are voluntary local organizations of farmers and ranchers who wish to save their lands from further erosion by adopting agricultural practices that will restore and preserve the soil. As of October 1944, there were 1,169 such local soil conservation districts covering approximately 650 million acres in 45 States.

The Soil Conservation Service has shown that of its 59 time-tested soil-conservation practices, all assist indirectly in bringing back wildlife, while several methods, where applicable, bring a direct increase almost at once, often with cash benefits in the form of fur or food fish. These methods include marsh development and management, beaver management, stock pond development, stream bank protection, and range reseeding. "Even in the Southwest, farm ponds of Arizona and New Mexico show promise of becoming highly productive,"[61] thus affording both food and recreation.

Development and protection of vegetation on odd corners, or on wastelands and gullies that can no longer be used for any regular agricultural purpose, has not only prevented further loss of soil, but has produced large quantities of wildlife, particularly game birds, having a high recreational value. Often this wildlife could not otherwise have found any suitable habitat in the region. The Service has stated that in the United States as a whole, 5,641,300 acres of otherwise unusable land can be reclaimed for this purpose.

Range management.—Soil erosion and range surveys have been carried on by the Soil Conservation Service throughout the country, but actual restoration projects so far have been concentrated to a considerable extent upon farm lands, particularly in eastern States. In western regions, including the Colorado River Basin, vast grazing areas lie in the public domain. This range land is administered by Federal agencies, and is not adapted to voluntary organization by small agriculturists into soil conservation districts. In 1938, an interdepartmental board was created to facilitate cooperation in soil conservation between the Soil Conservation Service and other Federal agencies, including the Forest Service, National Park Service, and the Bureau of Indian Affairs. One of the most important projects of the Soil Conservation Service in the Colorado River Basin has been its joint demonstration with the Bureau of Indian Affairs of range management on the severely overgrazed Navajo Indian Reservation.

Much of the land in the Colorado River Basin is administered by the Bureau of Land Management of the Department of the Interior. The Taylor Grazing Act, establishing the Grazing Service, now incorporated in the Bureau of Land Management, was passed by Congress in 1934 to protect the public domain from the unregulated and destructive grazing that had existed since the first days of settlement, and to provide for the orderly development and restoration of the range.

Considering the enormous loss of forage and topsoil that had taken place before the creation of the Grazing Service by this act, subsequent progress in restoration of the land, though slow, gives room for hope. Livestock has been better distributed by the extensive development of springs and stock reservoirs. Wildlife has benefited not only from the water development but from the more equalized distribution of the livestock, with its attendant lessening of overgrazing.

Grazing regulations provide that "a sufficient grazing capacity of Federal range will be reserved for the maintenance of a reasonable number of wild game animals to use the range in common with domestic livestock." Although the feeling is by no means universal, many stockmen definitely favor game conservation, and are willing to support any measures for its restoration that do not seriously interfere with the numbers and welfare of their livestock.

Although the Bureau of Land Management receives no funds for wildlife conservation, and any progress in that direction is voluntary or incidental, a noticeable increase in various game species appears to have resulted from such range improvements as have been accomplished to date. Many Bureau of Land Management field men serve as volunteer deputy game wardens, and there is con-

[61] Graham, 1945, p. 219.

siderable cooperation on specific wildlife problems with local sportsmen, State conservation agencies, and Federal departments.

Proper regulation of the numbers of livestock and of the duration of the grazing season on the grazing allotments is one of the most important conservation functions of the Bureau of Land Management, because the only hope of restoring soil and plant cover lies in that direction. Control of the number of livestock grazed on the public domain is achieved in part by allotting grazing areas and permits only to soundly established local operators who have a personal stake in the future of the land, thereby eliminating the reckless competition between owners of transient livestock that characterized the early days of unregulated exploitation.

Decisions as to numbers of livestock to be granted under each permit are made by the local Bureau of Land Management representatives, and are passed on by the local advisory boards. The latter are composed of cattlemen and sheepmen elected by the users of the range, and one wildlife representative who is appointed by the Secretary of the Interior on the recommendation of the State fish and game department of the area. Although the local advisory boards are without executive authority, their general attitude is naturally an influential factor in local range policy, including any proposed program of curtailing the present numbers of livestock in order to improve the ultimate carrying capacity of the range. Obviously, effective range restoration requires that the technical knowledge of the local Bureau of Land Management representatives be supported by an enlightened outlook regarding modern principles of range management on the part of these boards.

Public education in conservation.—The awakening of the public, and of the law-making representatives of the public, to an understanding of the basic importance of soils and waters, and the magnitude of the Nation's losses in terms of them, has hardly commenced.

Scattered, uncoordinated efforts are made in this direction by many public-spirited agencies and individuals, but the total effort lacks focus, and for the most part reaches only those who already are converts, while millions of the general public remain almost totally unaware that a problem which may be soberly assessed as a national catastrophe even exists.

There is a demand by conservation organizations and schools for information on the work of the State fish and game departments. The latter try to fill this need, often with less than adequate funds to develop their educational programs. Beautiful pictures of wild animals often are shown, and heartening progress told of restocking activities, but seldom is there mention of the basic importance to the country of soil and water, their present plight, and the possible methods of restoration. Educational activities of most of the Federal conservation agencies, too, tend to stress the pleasant facts of accomplishment, omitting reference to problems that might arouse public inquiry and concern.

The Forest Service wages a vital educational campaign against forest fires. The Bureau of Land Management is conducting a long-range campaign of practical education to demonstrate to stockmen that conservative grazing yields more pounds of beef and mutton, and more money in the long run than overgrazing, but appropriations received for this phase of the work are hardly on a scale with the need, and meanwhile soil erosion caused by overgrazing continues to drain away the life-substance of millions of acres.

The National Park Service endeavors to maintain the areas under its jurisdiction as complete wildlife sanctuaries. It also stresses the importance of watershed protection in many of its educational programs. Nevertheless, for the most part, it has not been possible to present a clear-cut picture that will enable the general public to understand the basic reason why an ungrazed area with fertile topsoil, held in place by healthy vegetation within the parks, produces more abundant wildlife, clearer and better stocked trout streams, finer forests, and many more flower-covered mountain meadows than a comparable but overgrazed area. Such education in the fundamentals of soils and waters undoubtedly would enlist more active public support for the Service in its efforts to eliminate overgrazing from places like Saguaro National Mounment, where the natural conditions which led to the establishment of the area have been practically destroyed.

The schools, for the most part, have missed their conservation opportunity just as completely. As a former director of the Fish and Wildlife Service has pointed out,[62] the history books of the West tell of the great wealth derived from the early fur trade and the enormous fortunes established by the cattle kings, but fail to mention that sheer wastefulness brought an end to that era; and, more importantly, that even today good conservation practices eventually could restore that wealth to many of the lands and waters of the West.

At the education level of the universities seldom is the enormous wastage of water pollution, soil loss, and general land mismanagement really driven home. At present relatively few university graduates are aware of the existence of a national soil erosion problem. Yet it is from this class of educated persons that many of the principal ideas for future development of our country will come.

In the field of fundamental conservation education, the work of the Soil Conservation Service has been exceptional, in part no doubt because this agency was especially created for the purpose, whereas the education program of the Fish and Wildlife Service[63] and other agencies have had to be incidental to other primary responsibilities. Probably this circumstance points to the major defect in our entire conservation-education set-up. Though it is basic to the future prosperity of the Nation, now that frontiers are dwindling and population-saturation is approaching, conservation education, for the most part, has been merely an unorganized labor of love, and not the primary responsibility of any definite agency. To quote from the Secretary of the U. S. Senate Special Committee on Conservation of Wildlife Resources:

> I believe, therefore, that the greatest conservation problem that confronts us today is that of conserving our soil. And this can only be accomplished by fundamental understanding brought about by education, both in the school and the political arena.[64]

Wildlife research.—Comprehensive research on habitat requirements and methods of increasing wildlife was commenced on a small scale more than 30 years ago. In 1911, the Committee of Inquiry on Grouse Disease, in England, published results of an exhaustive study of the red grouse that was a remarkable forerunner of modern wildlife management investigations. Studies of the food habits of many birds as they affected agriculture, including methods of encouraging beneficial species and controlling injurious kinds, was undertaken in the United States by the Bureau of Biological Survey (now the Fish and Wildlife Service) at an even earlier date, and carried on over many years, but the concept of wildlife management had not been developed in America at that time.

The viewpoint that wildlife is a direct product of the land, to be increased by restoring the appropriate environment and growing conditions, and, where desired, to be harvested (hunted) according to a definite plan, with a definite financial return like any other crop, was first emphasized in this country during the early 1930's by the pioneer work of Leopold (1931a, b; 1933) and Stoddard (1932). Such a tangible and "practical" concept had Nation-wide appeal and was used to enlist the active support of sportmen's groups, various commercial interests, and many persons of political importance who had been beyond the reach of most previous conservation efforts.

The new game management idea stimulated the investment of an unprecedented volume of public and private funds in wildlife restoration for recreation purposes. In 1935, the American Wildlife Institute aided in establishing nine Regional Wildlife Research Units centered at State universities that had agreed upon a cooperative research program with the Bureau of Biological Survey (now Fish and Wildlife Service) and the respective fish and game departments. By 1944, publications covering the findings numbered more than 500, with many more expected.[65]

In 1937, Congress passed the Pittman-Robertson Act, which uses some of the Federal excise tax funds derived from the sale of sporting arms and ammunition to aid the States in the improvement of depleted wildlife ranges, and for scientific research on problems of wildlife depletion and restoration. The States are required to meet Federal allocations of funds with contributions in the ratio of 1 to 3. Only a part of the total tax receipts has been uti-

[62] Gabrielson, 1945a, p. 206.
[63] Gabrielson, 1945a, p. 208.
[64] Shoemaker, 1945, p. 359.
[65] Gabrielson, 1945b, p. 28.

lized for this conservation program but the annual amount allocated to all States rose from $1,000,000 in 1939, to $2,750,000 in 1942, after which war conditions brought a decline.

Direct restoration of wildlife habitat and the acquisition of winter range have been made possible in numerous areas through use of these funds. In the Colorado River Basin, lands have been acquired for the restoration of antelope, prairie chickens, wild turkeys, and deer. Surplus antelope, buffalo, beaver, wild turkeys, and other wildlife have been removed from crowded ranges to other areas where restocking was needed.

The financial support given by the Pittman-Robertson Act has been responsible for a vast quantity of the basic studies that are essential to Nation-wide restoration of soils, waters, and wildlife. Some of the projects undertaken in the basin include State-wide wildlife surveys, fur resource surveys and big game counts, inventories of water facilities for desert game, studies of the habitat requirements of beaver, mule deer, sage hens, sharp-tailed grouse, and wild turkeys.

Research on wildlife restoration and its relation to the conservation of soil, moisture, and vegetation now proceeds so rapidly upon so many fronts that the technical worker no longer can be familiar with all developments. He is fortunate if he can find time to keep abreast of new discoveries in his restricted field.

Despite this progress, the biological problems involved in wildlife restoration and recreational use are so complicated, and differ in so many vital details from one species to another, that the field has been relatively untouched. Its state of advancement and flux in this respect might be compared with that of the field of medicine, wherein many old problems still remain unsolved, while at the same time, fresh discoveries continually open up great possibilities of progress in new directions.

Restoration has commenced but lags behind knowledge.—Restoration measures have brought good, if limited, results. Elk and deer have shown better recovery than almost any other game animal. In Colorado, elk have been increased from 1,000 in 1910, to 24,000 in 1945, and most of the original refuges in Colorado now have been opened to shooting. The numbers of animals exceed the range capacity in several areas, with resultant damage to range plants and soil, and to adjacent agricultural areas.[66] Return to primitive numbers, of course, always will be impossible because the best part of the original range, which lies in the valleys, has been converted to agriculture.

In Arizona and New Mexico, the native Merriam elk was completely exterminated in the early 1900's. The Rocky Mountain elk was introduced in 1912, and has multiplied until the total number on national forest lands is now estimated at 4,100 in Arizona and 1,500 in New Mexico.[67] This total is encouraging, even if it is not comparable with the thousands that once roamed the mountains and valleys, and is sufficient to permit considerable hunting.

Utah's elk herds also are drastically restricted in numbers by the extent of the remaining range, but limited hunting recently has been possible each year.[68] In Wyoming, the elk have survived in something like their original numbers. The Jackson Hole region, immediately north and west of the Colorado River Basin, is nationally famous as a big game center; however, the region was not considered particularly good game country by the pioneers as compared to what were then the more hospitable game ranges in parts of the Colorado River Basin to the south.

Deer have been restored beyond all possibility of danger. In fact, the deer problem of the Colorado River Basin and elsewhere in the West today is for the most part one of overabundance that seriously threatens the future of the range. Efforts to reduce the deer herds to the carrying capacity of the range have been complicated in many areas by the near extermination of the mountain lions, which in primitive times usually acted as a vital forest-protection agent by keeping the deer within the carrying capacity of the range.

Man through hunting has attempted to take over the control program formerly carried out by the lions, but with less success. In the early days of settlement, he overcontrolled the deer to the verge of extinction in large areas. Later, when he had removed the lions, he let the deer population increase out of all bounds, so that they crippled for-

[66] Swift, 1945a.

[67] Swift, 1945b, p. 123.

[68] Utah State Fish and Game Commission, 1944, p. 11.

est reproduction for decades, and then starved by thousands. The Kaibab Plateau on the north side of the Grand Canyon is the most often quoted example of this mismanagement. "There a small herd of about one-tenth of the 1928 herd is about all the range can safely carry at the present time."[69]

In still more recent times, game management techniques have furnished a key to reasonable control of deer, but if the hunter is to be effective in replacing the mountain lion in Nature's deer-reproduction program, he may find it more and more necessary to discard certain biologically unsound habits not shared by the lion, such as the selective killing of males only.

Antelope have increased sufficiently in certain parts of New Mexico, Arizona, Colorado, and Wyoming to permit a limited open season, but the numbers and distribution of these animals are but a fraction of that which originally prevailed in the country as a whole.

> The preservation of antelope is synonymous with the restoration of grassland which constitutes one of our greatest and most important conservation problems. It does not take keen scientific observation to see that "grazing refuge" rather than "hunting refuge" is the urgent need of the antelope range at present. Provisions should be made in each district for antelope in common with livestock.[70]

The buffalo millions are represented in the Colorado River Basin by a herd of approximately 200 head in House Rock Valley in northern Arizona, a band of about 28 in the vicinity of the Henry Mountains in southern Utah, a small herd on or near Anderson Mesa, and 31 head in Colorado National Monument. Forage in House Rock Valley is poor and the herd has to be reduced periodically. Forage is scanty in the vicinity of the Henry Mountains, although this band is still increasing. Forage conditions in Colorado National Monument are deplorable. A substantial reduction in the number of buffalo there had to be made in 1945, but a still greater reduction is needed.

Bighorn, though protected everywhere, have for the most part continued to dwindle in the Colorado River Basin, although perhaps at a slower rate than during the depression years, when poaching by "prospectors" was more common. In Arizona, "certain localities will see the last of the Bighorn within the next decade. However, the outlook is better for those remaining in Yuma and Mohave counties."[71] In New Mexico, only three bands of native bighorn appear to remain, none of them being in the Colorado River Basin.[72] In Utah, there were at one time many along the gorges of the Green and Colorado Rivers. They are still fairly common there, but local residents state that their numbers have been greatly reduced in recent years, apparently by the widely observed epidemics of scabies, which seem to have been transmitted by domestic sheep. A few bighorn remain along the high plateau lands from Zion National Park to the Uinta Mountains. In Colorado and Wyoming, the bighorn may have ceased their downward trend in some localities. In Pike National Forest, Colo., which is outside of the Colorado River Basin, good summer and winter forage on the Tarryall Range has permitted the bighorn to increase to about 600, and the surplus is being used to restock other localities.

Beaver, bears, and peccaries are said to have increased since 1943,[73] but such statements are relative and require qualification. Beaver restocking programs have been carried out in Arizona, New Mexico, Utah, and Colorado, but as a rule only the more remote and less productive areas are suitable for beaver today. The animals must be kept out of many agricultural regions which formerly were their most fertile habitat because of the damage that they do to crops, irrigation canals, aqueducts, and highways. Less than 10 percent of the original beaver habitat has been restored. In the Colorado River Basin the once abundant black bear has increased in some places, but the grizzly, which was distributed throughout most of the mountains and foothills, now is extinct, except perhaps at the extreme northern end of the basin near Jackson Hole. The peccary, at one time threatened with extinction, was given total protection in the 1930's and has recovered sufficiently for an open season to be declared in Arizona. In New Mexico, they were reported from the Coronado National Forest in 1943, but from none of the other national forests,[74]

[69] Swift, 1945b, p. 132.
[70] Knipe, 1944, p. 38.
[71] Arizona Game and Fish Commission, 1942, p. 16.
[72] Halloran, 1944.
[73] Swift, 1945b, p. 121.
[74] Swift, 1945b, p. 123.

although prior to 1912 their range in the State had been considerably greater.[75]

The progress in restoration outlined here is incomplete, but it is typical of the brighter side of the picture. A start has been made in the right direction, but we still have a long way to go. Waterfowl, for example, have recovered miraculously in the last few years, due in part to a lessening of hunting pressure as a result of war conditions.

> But events of the next few years will show whether the administrators and sportsmen are able to perpetuate this "miracle." The army of hunters is sure to increase with a resultant increase in the pressure that will be exerted against all wildlife. The ability of nature to meet the demand will depend in no small part upon the wisdom and reason that is exhibited by all those who regulate for and participate in sports afield.[76]

In spite of game laws, game refuges, restocking, soil conservation activity on many farms, an increasing knowledge of range management, and a start in the field of public education, nevertheless,

> . . . wildlife habitat in fertile regions is being destroyed faster than it is being rebuilt . . . A general disorganization of the wildlife community seems to be taking place (and) private initiative in wildlife management has grown very slowly.[77]

> The Forest Service and now the Grazing Service have improved the management of ranges that have been eaten into the ground during the years of free range and destructive competition . . . (but) though the principles of good range management are widely accepted among stock raisers, the application of these principles is still far from universal. . . . Even on national forests and grazing districts the conservation of range resources is often below standards set by administrative officers.[78]

Examples of this difference between theoretical standards and actual practice can be found on the range land of any township picked at random in the Colorado River Basin. Such an example is furnished by Elk Ridge in southeastern Utah. In many places there is no grass left, merely trees, brush, and between them bare earth. When it rains, this bare earth turns to mud and washes down the slopes or is further trampled by the wandering bands of cattle so that seedlings cannot get a start. On some open flats that once were meadows, only thistles and other inedible weeds now can grow, and these flats are becoming gullied by run-off waters formerly held in place by grass sod.

Some of the gullies are still small and could be checked if an effort were made soon to save this once beautiful mountain meadowland. Other gullies, like the one in nearby Dark Canyon, have become canyons large enough to swallow a house as a result of the overgrazing.[79] They have drained the surface waters from adjacent meadow levels so that only weeds and dry-soil shrubs now can exist where once there was lush grass. Another 20 years will see the meadows of Elk Ridge transformed into gullied barren lands unless the grazing is placed upon a sustained yield basis. Erosion of this type on the recreational lands of the country is glaringly obvious to persons trained to observe it, but to the average fisherman and camper, realization of the destruction is more likely to come 50 years too late.

Complacency over progress in plant and animal restoration is unwarranted so long as the wildlife winter range areas are in their present condition. Even though deer and elk have been forced by civilization to move into the mountains, it has been physically impossible for all of them to remain at the higher levels all winter. Although they no longer come so far into the valleys as in the early days, they usually move from the areas of deep snow down into the lower foothills in winter.

In the Colorado River Basin and elsewhere in the West, winter range is almost everywhere the area of limited forage for game. The problem is further aggravated by the fact that the heavily used winter range of wildlife often is the same area that livestock men use most heavily in the spring.

Spring range for livestock often is abused more than any other seasonal range because the stockmen are anxious to take their herds away from the home ranch where winter pasture often is short and hay feeding a large expense. As a result of this haste to leave the winter feed grounds, the livestock all too often are put on the spring range while the soil

[75] Bailey, 1931, p. 11.

[76] Fish and Wildlife Service, 1945, p. 1.

[77] Leopold, 1945, p. 165.

[78] Presnall, 1945, p. 225.

[79] Woods, 1944, p. 885.

still is too wet, which causes severe damage to the sod by trampling. The forage itself is far less able to withstand grazing pressure during the early spring growth state than at any other time, because the young plants have not yet been able to store up sufficient food in their roots and stems. Plants that are grazed before they have stored up their vital food supplies never can make normal growth thereafter. Often they fail to produce seed at all, and if this too-early grazing is continued year after year, they are gradually exterminated.

Progress in solving the problem of winter range for wildlife will be slight until the following mistakes are corrected: (1) Too much reliance on artificial feeding of wildlife. Either the numbers should be reduced to the carrying capacity of the range or additional winter range should be acquired. (Acquisition of key areas for winter range has been an important Pittman-Robertson Act contribution in some States of the basin.) (2) Lack of realization that lands available for winter use by game are rapidly being withdrawn for other uses by man. (3) Tendency to give attention to methods of hunting, effects of predators, poaching, and lengths and dates of open and closed seasons, rather than to the real issue, which is lack of adequate winter range.[80]

The species which have shown the best increases are principally forest dwellers. Some wildlife of the open range, like the antelope, has recovered to some extent, but even with this species the limits imposed on the extent of recovery by overgrazing have been pointed out. The sage hen has shown a small recovery but is similarly limited. That the bighorn owes its decline at least in part to the depletion of forage will be brought out later. The sharptailed grouse

> represents one of our definitely vanishing game species . . . Studies have shown the limiting factor to be the disappearance of suitable habitat for this species. The cultivation, overgrazing, and burning of their natural range has limited it to small islands at the present time. Here is an example where propagating and planting of additional birds could not benefit the birds unless the habitat conditions are corrected.[81]

The rarer fur bearers, particularly martens, wolverines, and fishers, are showing little or no recovery. Hardly anyone knows what a fisher is and few wildlife men actually have seen one. These species so far have been raised with little or no success in captivity. They represent one of the few cases where habitat destruction is not involved, for millions of areas of suitable forest land still are available. Some regulations have been passed, but the actual enforcement of protection measures in winter wilderness areas has been inadequate.[82] Martens are fairly numerous in the mountain forests of the Colorado River Basin, but a Forest Service census for the entire area includes no fishers, and only five wolverines in the extreme northern end of the basin.[83] Formerly all three species occurred in the higher mountains at least as far south as the north lines of Arizona and New Mexico. In 1938, it was officially conceded that "The trapping of fur bearers on the national forests is without benefit of any system of management or control of trapping efforts."[84] Postwar plans eventually may change this.

Another species that is not far from extinction is the otter. No otters were listed by the Forest Service in 1943 for national forests in the Colorado River Basin.[85] However, in Arizona, "there is a small colony on Clear Creek and two or more colonies on the lower stretches of Rock Ruin River.[86]

Meanwhile millions of tons of soil continue to wash away needlessly. In the Southwest and elsewhere, permissible grazing capacity has long since been exceeded and "vegetation now is far from adequate to protect the surface against the erosive forces."[87] The following statements for Utah summarize the situation for nearly all of the Colorado River Basin and afford no reason for complacency:

> Range conditions over our state generally show little improvement over those of the last two decades, excepting in some areas where Federal Agencies have been able to improve them. The Forest Service through restricting of grazing, and through better range management practices, has been able to improve several areas. The Grazing Service and the Soil Conservation Service through their activities have

[80] Murie, 1944.

[81] Utah Fish and Game Commission, 1940, p. 6.

[82] Beard *et al*, 1942, p. 79.

[83] Swift, 1945b, p. 135.

[84] Beard *et al*, 1942, p. 87.

[85] Swift, 1945b, p. 134.

[86] A. A. Nichol, letter, Dec. 29, 1945.

[87] Thornthwaite *et al*, 1942, p. 127.

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demonstrated very plainly the possibility of restoring badly over-used ranges. Much of our range land is yet in need of immediate attention. The drouth of the past few years, although not the primary cause, has added to the range problem.

Game has been blamed by some for the conditions in over-grazed areas, but investigation shows in the main, the areas hardest hit have no game upon them. We refer to those large areas known as the east and west deserts of Utah, areas where the original plant cover has been greatly changed and many of the valuable species replaced by less desirable ones.

The excessive grazing practiced is resulting in floods sweeping down, cutting our canyons deeper; depositing debris on the more valuable lands in the valleys; and causing a general decadence to come to our agricultural, livestock, and wildlife interests.

Unless we give our soils a more reasonable use and employ better methods of grazing, much of our land is going to pass into a sub-marginal state and this type of land means a sub-marginal people.[88]

In spite of this growth in the understanding stockmen have of the need for management, and in spite of considerable progress on much of the range area, the grazing problem is by no means solved. The Forest Service, oldest federal agency to conduct a continuous program of managed grazing, in its later canvasses of the condition of ranges and watersheds in the West, found that many of them were still in a deteriorated condition. Some of these ranges can be much improved, and in fact have been. For example, many range lands under private ownership have been built up or maintained in good condition. In far too many cases, however, damage has been done to the plant cover and the soil mantle. Until these conditions are corrected, no one really should feel that we have surmounted the grazing difficulties or stemmed the tide of forces that bring about deterioration. Some important citizens, however, still express the opinion that domestic livestock are not primarily responsible for serious damage to the range. It is maintained that as ranges begin to deteriorate, but before serious damage is done, the economics of the situation cause stockmen to cease or lighten the use of the range so that it is an economic impossibility to damage a range permanently through overgrazing by livestock.[89]

It is certainly contrary to sound economics to so damage a range, but such uneconomic practices continually occur.

This lack of understanding of the basic importance of soil and water on the part of "important citizens" is symptomatic of the entire problem which faces today's restoration program. Research and the gathering of facts have far outstripped public education. The technicians in the agencies devoted to land planning are well aware of the depletion, as are most of the administrators. The difficulty is that the administrators, far from receiving strong public approval and support in any program to restrict range and soil abuse, usually are subject to an intensity of local opposition that is in direct proportion to the extent of their proposed reforms. Thus the problem becomes one of gaining public support to carry out what it is already known should be done.

Public realization of the present destruction lags behind our technical knowledge of what needs to be done. In the last analysis, the future of the land and water, of plants and wildlife, of recreation, and of man himself lies in the outcome of a race now under way between the forces of land destruction and the slow growth of public education.

GRAZING A BASIN INDUSTRY THAT NEEDS STABILIZATION

More square miles in the Colorado River Basin are devoted to grazing than to any other industry. The land is ideally suited to this purpose, but was ruinously depleted in the early days by improper grazing methods and can be restored now only by adjusting the number of animals to the present carrying capacity of the land. The various administrative agencies now in charge of grazing in the basin know what has happened to the soil, water, and forage. They have worked out methods for putting grazing on a sound economic basis that

[88] Utah Fish and Game Commission, 1940, p. 12.

[89] Woods, 1944, p. 881.

could restore the range and at the same time bring prosperity and permanency to the grazing industry. But because use of the western range is governed by democratic processes and is dependent upon the will of the people, the administrative agencies can only go as far in the direction of restoration as public opinion will support them.

At present the average person is unaware of the existence of overgrazing and has even less knowledge of the profound destruction which it brings to the land. Therefore, public information—presented by an interesting and effective program rather than as a dose of unpalatable medicine—is fundamentally the solution of grazing problems.

PUBLIC INFORMATION AND MORE SUPPORT FOR CONSERVATION ARE FUNDAMENTAL NEEDS

The problem of determining the proper uses of the Colorado River Basin is largely one of conserving its basic soil and waters. The present economic-use pattern is a product of various natural conditions, and in general seems well adapted to the land. What is principally needed is the replacement of destructive methods by up-to-date methods with respect to existing land uses. Knowledge of how to do this is readily available, but the program cannot be carried out without public support. Therefore, a more effective program of public information is essential.

The public is uninformed regarding basic conservation issues largely because conservation education has lacked focus. Scattered, uncoordinated efforts are made in this direction by innumerable State and Federal agencies, and by private individuals, but never on a scale that has been adequate for a Nation of more than 140 million persons. The Fish and Wildlife Service has outlined the failure of past conservation efforts to meet the vital need of public understanding. It has indicated three major steps that are essential to an improvement of this situation, together with its own well-thought-out postwar plans for meeting its share of the education responsibility. Yet this agency is forced to admit, as would practically all others throughout the land, "that such efforts as the Fish and Wildlife Service has been able to make in this field are largely sporadic in character and occur as the result of the overwhelming interest in the program, or some part of it, on the part of the individuals in the Service."[90] Conservation education funds and enabling legislation never have been adequate for this or any other agency.

It is true that some progress in conservation has been made, but as previously emphasized, the deterioration of soils and waters and the destruction of recreation values continues. If these destructive processes had not been going on for more than 70 years there might still be time to let public education catch up without assistance—except for the fact that public realization of this kind of destruction seldom dawns until the emergency stage has been passed.

Adequate staffs and funds are needed for conservation education, *now*. Enough of the basic research in range management, soil conservation, and wildlife production has been accomplished to furnish a clear-cut initial restoration program. The basic knowledge already is in the hands of the technicians and administrators, and only needs to be made available to the general public to gain support. But acquainting the public with the facts will be a full-time job.

Re-education of land users away from some of the old-time destructive soil practices will require not only the special techniques and full-time energies of all conservation organizations, but considerable tact and some salesmanship, as well as the fervor that comes from a genuine conviction as to the urgency of the work. That good results really can come from an educational program based on such a point of view has been well demonstrated by the education-demonstration results achieved by the Soil Conservation Service and the Bureau of Indian Affairs.

The educational programs of the conservation agencies would include the introduction of a really fundamental conservation program into the schools.

> In the past many of these efforts have been too limited in scope of material included, and too narrow in their appeal to take the next step and present the basic philosophy. In other words, children have been taught to appreciate birds or trees or flowers or something else without being given a basic understanding of the total interrelationships of each to the other

[90] Gabrielson, 1945a, p. 209.

and of all forms of life to the manner in which we manage the soil and waters of America.[91]

It would also be a function of the conservation agencies to stress existing conservation information and entertainment materials. At present, beautiful pictures of scenery or wildlife are too often shown in educational programs without any attempt to follow through with the basic information showing the fundamental reasons *why* a famous cactus forest is disappearing or *why* a certain wildlife species needs a particular feeding area if it is to survive. Experience in public education has shown that far from being tedious, this additional information, that gives point to the story, is eagerly accepted by the general public. However, the preparation of material containing this additional interest and critical focus is a full-time job for professional staffs.

There is no doubt that if such a conservation-education agency were established on an adequate basis, a very few years would bring a great increase in public support for the additional refuges, enlarged research staffs, new equipment, and the increased appropriations that are now so urgently, though for the most part fruitlessly, requested by the various conservation agencies.

To any suggestion that Federal agencies embark upon an accelerated program of "education," there usually arises an objection to "regimented thinking" or the dissemination of "propaganda." The cooperative public demonstration methods so successfully used by the Soil Conservation Service might indicate the general answer to this objection. In any event, the education or information program should be conceived not as an attempt to force public thought along certain lines, but rather as a *duty* on the part of the Government to acquaint all the people with the *facts* covering basic interrelations of soil, water, plants, animals, and recreation, and their importance to national prosperity and contentment. If a really adequate presentation of the facts is given, the public can be relied upon to support the necessary program of conservation.

[91] Gabrielson, 1945a, p. 205.

CHAPTER IV

Prehistory of Man

Wherever one travels in the Colorado River Basin he is certain to be impressed, sooner or later, with the abundant and basin-wide evidence of prehistoric occupation and use by man—extensive ruins of ancient buildings; early camp sites strewn with broken pieces of pottery; shaped stones; ancient ears of corn; and strange symbols and drawings on rocks and cliffs. Curiosity and interest are immediately aroused. Exploring the ruins and learning the dramatic story of these early peoples is one of the recreational activities of the basin. These evidences of prehistoric settlement and use of the lands and waters of the Colorado River Basin constitute a resource of important recreational and historical significance—of unique and irreplaceable value to the Nation.

Nowhere in America is the story of man's struggle with environment so vividly told. Here, to survive, man had to develop an uncommonly keen sense of things about him. He had to know what plants were natural providers of food and where they grew; the habits of game animals; how to go from place to place over long waterless wastes; the location of fertile lands for planting and how best to coax his crops from these lands, whether by taking advantage of natural subsurface moisture or by directing water to them by means of canals; and above all the source of water, the elemental necessity for human existence, affecting directly, along with the food supply, the stability and population density of a sedentary people. Since geography plays such an important part in determining the pattern of culture of a people, the following review of man's history in the Colorado River Basin must consider the physical environment as the back drop against which the cultural achievements can be projected.

The archeological story of this region is laid essentially in the valleys, for here the prerequisites of land and water were at their best. And our modern twentieth century civilization follows precisely the same pattern, since water is still the most precious asset of this entire region. Consequently, the priceless and irreplaceable ruins and relics of the prehistoric peoples of the region are found concentrated primarily along the streams—including the major waterways which modern civilization is essaying to control and harness. As the reservoirs rise behind the new dams, and as lands below are modified, archeological remains not excavated in advance will be forever lost.

It was the permanence of abode—dictated by the tremendous investment in the construction of the canal systems by the people along the Gila and Salt Rivers, or the labor expended in the founding of great communal settlements, the Pueblo apartment houses of the Colorado Plateau, wherever land and water permitted—that led to the notable achievements for which the native folk here have become renowned.

As pointed out in Chapter I, the full range of environmental types, from the hot, barren, inhospitable desert to the cool, forested altitudes of the mountains, is found within the basin. Accordingly, the archeological picture is exceedingly complex and the following review is not more than a brief inspection of the general historical and cultural elements.

EARLY MAN IN THE SOUTHWEST

The story begins more than 10,000 years ago, before the cooling effects of the last great ice sheet of northern North America had been completely dissipated by a changing climate. The basin was both cooler and moister than it is today. What is now a parched land was heavily grassed over and seamed with tree-lined streams. Introduce into this picture such animals as the mammoth, camel, horse, ground sloth, tapir, wide-horned bison, and

four-horned antelope, all animals which have since disappeared from the scene. (The modern horse was reintroduced in recent times.) Finally also usher in man, a hunter and gatherer of Nature's foods, a relative newcomer to a new world from northern Asia via the Bering Strait route.

These probable ancestors of the present-day American Indian began wandering southward through the continent, eventually to emerge in the valleys and on the plateaus of what is now the southwestern United States. While many of these peoples of this and later migrations spread widely over the continent and south across the Isthmus of Panama and throughout South America, some remained in the desert and mountain regions of the Colorado River Basin to become the Southwest's first pioneers.

Cochise Culture.—In southeastern Arizona, erosion during the past 50 years by such streams as San Simon Creek, San Pedro River, and others, has exposed deep below the present surface the camp sites of one of Arizona's earliest people, the Cochise Culture. Fortunately, the accumulated natural overburden of clays, silts, sands, and the like, mirror the geological events of bygone millenia and provide the student of past climate with a measure of time. Expert opinion places the age of the oldest tools of Cochise Man, covered by and imbedded in the deposits laid down in a moist period, as older than 10,000 years. These tools consist mainly of milling stones and hand stones, primitive choppers and scrapers, all indicative of a food-gathering economy which exploited native vegetal foods, as contrasted to the use of projectile points and fine-cutting implements associated with the Folsom hunters of the high plains east of the Rocky Mountains. The animals of the time included the mammoth, horse, bison, camel, and a large wolf, all of which have since vanished from the scene.

In the same region where the evidences of Cochise Man have been found, occur also traces of a later people, assignable to two successive periods of time on a geological basis. They persisted through the periods when climate was changing from the moister, cooler type towards the climate we have today, and the animals were modern, or those which still inhabit the area. The record of

Figure 33.—An Indian ruin on the Verde River—Tuzigoot National Monument, Ariz.

these people ends about the time of Christ, when profound changes in the whole cultural make-up are recorded.

Because of similarities between the tools and the way of life of these people and the still earlier Cochise Culture, a continuity of occupation has been inferred, giving us, in fact, an inkling of human affairs in this region over thousands of years rather than for centuries, and supplying information, though sketchy, through that long interval between the truly ancient native American and his younger successor of the time of Christ, an interval which elsewhere has not as yet been filled in.

Ventana Cave.—How widely the people we call the Cochise Culture ranged through the Southwest at this remote time still remains to be determined, but telltale traces have been found beyond the reaches of the southeastern tributaries of the Colorado River in New Mexico and Old Mexico. To the west, within the Colorado River Basin, in the area now inhabited by the Papago Indians, an important cave (Ventana Cave) has recently been excavated, throwing further light on these people and their culture. This cave is located some 80 air-line miles west of Tucson and a comparable distance south of Phoenix. The significance of this cave lies in the fact that it was inhabited, with few interruptions, from almost the present time back to that distant era of moist climate approaching the last glacial period. Here the debris which accumulated through this long occupation appears layer upon layer in the order of time.

Figure 34.—Ventana Cave.

The tools of the Cochise Culture lie in the middle portion towards the base of a 15-foot-thick trash pile. Directly associated with these tools are other types of chipped stone implements, like those of the people of the lower Colorado River Basin and the Pinto and Mohave Basins of southeastern California, giving some indication of contemporary neighboring groups. But, more important is the fact that at the very bottom of Ventana Cave in a rocklike layer were a number of stone tools used by hunters and with them occurred the bones of extinct bison, sloth, tapir, horse, and the four-horned antelope. Some relationship with the Folsom hunters of the high plains is indicated, as well as with an early folk whose products have been found toward the mouth of the Colorado River. This material is considered, upon geologic evidence, as more than 10,000 years old.

Along the shores and terraces of ancient dry lakes and river beds in southeastern California and southern Nevada occur additional remains of Early Man. These include numerous camp sites and stone artifacts of early hunting and seed-gathering peoples. These camp sites are believed to have been occupied approximately eight to ten thousand years ago at a time when moist climatic conditions prevailed over the area. Distinctive types of projectile points set off these from the Cochise and Folsom Cultures to the east. Many of the animals so eagerly hunted by these ancient Indians have long since disappeared, becoming extinct during the next few thousand years. Among these animals were the native horse, camel, mammoth, wide-horned bison, and ground sloth. The giant ground sloth is of particular interest in this region because remains of the dung, hide, hair, and bones of this huge vegetarian have been found in a number of caves.

Gypsum Cave.—Gypsum Cave, located in a spur of the Frenchman Mountains a few miles northwest of Hoover Dam, is of primary importance. Excavation of this cave revealed several different culture horizons, ranging from modern Paiute Indian material on top, down through Pueblo and Basketmaker objects, to the bottom, where, below an intervening sterile layer, were fire hearths and man-made articles, together with bones of the ground sloth, camel, an extinct species of wolf, and the native horse. These earlier artifacts included a distinct type of projectile point, scrapers, cordage, and dart foreshafts and pieces of shafts, the latter often decorated with green, blue, and red pigments. Geologic evidence places this lowest level at about eight to nine thousand years ago.

Remnants of another, possibly allied, culture have also been found a few miles west of Gypsum Cave near Las Vegas, Nev. Here are similar projectile points and charcoal beds of old hearths occurring in open sites in strata that contain camel, horse, and bison bones. The same type points have also been discovered in a layer of horse dung in Etna Cave approximately 100 miles north of Gypsum Cave.

Little Colorado River Terrace Culture.—Farther to the east, along the Little Colorado River, extending from the vicinity of Cameron upstream to Holbrook, Ariz., are a series of prehistoric camp sites. These usually occur on the isolated flat tops of low hills and ridges representing all that remains of an ancient alluvial gravel terrace. The sites are all found at about the same general elevation above the river bed and consist of remnants of hearths and such associated percussion-flaked stone artifacts as crude hand axes, choppers, gouges, and keel-shaped scrapers. So far no projectile points that could definitely be allocated to this culture have been found. This so-called Little Colorado River Terrace Culture may be as old as the early occupation of Gypsum Cave.

Eden, Wyo.—Far to the north, near the headwaters of the Green River southeast of the town of Eden, Wyo., lies an extensive site of what has been called the Yuma Culture which centers east of the Rocky Mountains in the high plains. Here were discovered several varieties of the Yuma projectile points or knife blades, related to the famous Folsom points and similar in technique. They were found together with fossilized bison bones in sand and clay deposits, probably postglacial in age. In addition, many hand choppers and scrapers of what may prove to be an old culture occurred on gravel terraces and in sand blow outs in this same region and south along Blacks Fork Valley. Further excavations at the Eden site may furnish new data on the age of the Yuma Culture and on migration routes from the Great Plains into the Colorado Basin.

What all this adds up to is that man was here in the Colorado River Basin much longer than many of us have supposed and that the land, which now gives sustenance in abundance to modern man through planned use, was capable thousands of years ago of supporting a varied, though doubtless sparse, population.

The big task which confronts the archeologist is filling in the gap between the hunting and gathering peoples of roughly 10,000 years ago and the higher cultured folk, dating since the time of Christ, who added such elements as agriculture, pottery, and formal architecture to their roster of accomplishments. For much of America, this period is blank, placing the culture historian in a poor position when he endeavors to account for happenings in the interim.

With the possible exception of the archeological remains at Ventana Cave, there is a definite break at all sites between the older and later horizons of culture. As to just what happened over the intervening thousands of years, we can only conjecture. These earlier inhabitants may have entirely left the area and pushed farther to the south or, again, some may have remained and been joined by later bands of immigrants.

At all events, about the beginning of the Christian Era, profound changes were wrought among the native southwestern people by the introduction from the south, from what is now Mexico, of several important culture elements. Agricultural products, such as corn, beans, and squash, and the knowledge of how to grow them, must be given first importance. The adoption of agriculture induced a more sedentary and economically secure form of life, which, in turn, paved the way for further advances materially and socially. Agricul-

ture is and always has been the basis of all civilization, and here in America corn was the foundation upon which these later cultures were based. With the practice of agriculture, there arose an opportunity for group life, for the stimulation of mental activity by human contacts, with leisure for thought and invention. The art of making earthenware vessels, or pottery, was another addition, opening new opportunities for food preparation and storage, and providing a new outlet for aesthetic achievements.

As a consequence of the grafting of these features, and others too, to the simple nomadic life of the native people, the stage was then set for the development of several unique American civilizations whose characteristics and interrelationships have occupied the time of most southwestern archeologists up until now. On the Colorado Plateau arose the comparatively well-known Pueblo or Anasazi Culture, developing from the primitive Basketmaker and continuing through the historic period to the modern Pueblo. In the southern Arizona Desert, a quite distinct group known as the Hohokam was roughly contemporaneous with the Anasazi development. In the forested uplands between the plateau and the desert there was another basic culture, called Mogollon. Along the Lower Colorado River and in the western Arizona Desert there are sites, yet to be studied, of a little-known people designated as Patayan. And, although there is considerable overlapping of cultures in certain sections of the area, each of these basic cultures will be treated as a unit in the following discussion. (Plate 14, in pocket.)

Mogollon Culture.—In recent years, archeologists working in east-central and southeastern Arizona and adjoining parts of New Mexico, principally in the Upper Gila River System, have recognized what they believe to be an ancient tribe which was culturally distinct from the already identified Anasazi and Hohokam. This tribe has been called the Mogollon Culture (after the Mogollon Mountains and Plateau, which in turn were named for Don Juan Ignacio Flores de Mogollon, Captain General of New Mexico, 1712-15). The traces of these people consist chiefly of loosely organized villages of semi-subterranean dwellings, better known as pit houses. These people practiced earth burial, were agricultural up to a point, and relied quite heavily upon hunting and natural foods. They produced brown and red pottery of simple form but were generally laggard in the development of arts and crafts. They were not, in any sense of the word, a spectacular people, but to the culture historian they nevertheless occupy a prominent position in southwestern prehistory.

In the first place, there are reasons to believe that the Mogollon Culture is basically the connecting link between the pre-agricultural folk before the time of Christ and the later higher agriculturists. Early sites of the Mogollon Culture produce a number of stone implements which suggest a derivation from the latest stage of the Cochise Culture; or, expressed in another way, the chief difference between the two was the addition of pottery, agriculture, and perhaps a more formalized house type to the late Cochise complement of stone tools, to produce the oldest of several horizons of the Mogollon Culture. These new elements probably emanated from the south of Mexico, where native cultures were already somewhat farther along the road towards civilization.

A newly excavated village of these people in the Forestdale Valley, just below the Mogollon Rim, south of Showlow, Ariz., has given us tree-ring dates at about 300 A.D. The significant feature here is the fact that the residents of this village had a little pottery of brown color while their contemporary Anasazi neighbors to the north seem to have had no pottery. This sheds some light on a much-disputed point in southwestern prehistory as to whether pottery was locally invented, by whom, and when. It begins to appear that these people were among the earliest to know the ceramic art, undoubtedly introduced from the south as already stated, and that they were party to passing it on to other southwestern people. The same may be true of agriculture, although here more evidence is needed. Thus, while not creators of culture, the Mogollon people certainly aided in the early diffusion of the elements mentioned. Another excavated early Mogollon site is on the San Francisco River in southwestern New Mexico; others in this general area are farther east outside the Colorado drainage.

Their history is still far from complete, but we can say they did not achieve the illustrious heights of progress enjoyed by either the Hohokam or

Anasazi. At a relatively early time, perhaps by 700 A.D., they already were being assimilated by their more aggressive neighbors, the result being that after this time we lose sight of them as such.

It is interesting to speculate on the effect environment had on the Mogollon people. Their domain, for the most part, was rugged and forested territory below the Mogollon Rim stretching off in a southeasterly direction. This is a mountainous country running diagonally to the southeast, most of it forested, well-watered, and originally well-stocked with game, but deficient in the amount of land suitable for cultivation. Prominent features include the White Mountains at the southeastern end of the Mogollon Plateau and the Mogollon Mountains in western New Mexico in which the headwaters of the Gila River rise. There is no doubt that the Mogollon people farmed in favored localities, but these were limited, and so, while the Mogollon people knew the benefits of agriculture, they nevertheless followed the older form of food gathering too. And this latter pursuit gave them cause to move about, and to widen their territory and extend their range of contacts with other tribes. The area inhabited by the Mogollon Culture was as large as that claimed by their contemporaries, the Hohokam and Anasazi, and geographically they share equally with the others in any consideration of southwestern prehistory.

The foregoing remarks on the Mogollon Culture have by no means fully covered the archeology of the southeastern portion of the Colorado River Drainage Basin—other tribal groups also were involved, particularly after 700 to 800 A.D. They will be considered following the discussion of the Gila Basin and the White Mountains area.

Hohokam Culture.—The Gila River and its important tributaries, like the Salt, San Francisco, and Blue, rise in the great mountain mass of east-central Arizona and west-central New Mexico. From the high altitudes they descend through valleys and tortuous canyons, and eventually break forth on the lowland deserts of central and southwestern Arizona. Here the rivers become wide and sluggish, running between low channel banks carved out of the incredibly rich bottom land. These rivers, the Gila, Salt, and several minor branches, truly determined the development of a tribe known as the Hohokam (a Pima word meaning "the people who have gone"), farmers extraordinary and one of America's colorful pre-Columbian peoples. It was a case of Nature setting the stage and man's awareness of what could be done in spite of strong odds against him.

Just where the Hohokam came from and what their exact origin is remain moot questions. There are some indications that Hohokam, like the Mogollon people, were the descendants of an earlier local population. At any rate, we first begin to recognize them at about the beginning of the Christian Era and have traced their development for the ensuing 1,400 years.

They centered in the present region of Phoenix on the Salt River, and west of Florence on the Gila where the development reached its peak. The Hohokam frontiers lay far beyond this nuclear territory—west to Gila Bend, north towards Prescott (one contingent broke away from the core and went as far as Flagstaff), east into Tonto Basin and up the Gila to Safford, and southeasterly to about the Mexican border, notably in the valley of the Santa Cruz. To the south, close relatives of the Hohokam were at home. They will be discussed a little later on.

Rather than evidencing imperialistic tendencies on the part of the Hohokam, this large area of habitation indicates a natural expansion to those parts where they could follow the particular type of agriculture for which they are famous—irrigated agriculture.

Who it was among the Hohokam to first try ditch irrigation must forever remain an unsung hero. In fact, a single person may not have been responsible for this achievement. Like other basic steps of man to reach a higher state, it may have been the result of common striving where each contribution was infinitesimally small and perhaps unrecognized. In any event, perhaps by 500 A.D., or soon after, the Hohokam had learned enough to divert some of the water from the rivers along which they lived, and conduct it through artificially dug canals to the baked desert ground nearby. It took no great genius to see that more canals spelled more land under cultivation, which in turn would mean more food and greater economic security. But it did take leadership of a high order to muster and direct the labor to construct and maintain scores

of miles of ditches and to equitably distribute the water among a number of settlements on a single canal. The archeologist has no records to support the claim that the Hohokam were the originators of the "Water Users Association" idea, but prescribed rules and obligations must have been in effect.

To come down to specific examples, in the heyday of the Hohokam Culture, from about 1000 to 1400 A.D., the individual canals were both wider and longer than they were before or after this time, meaning that more land was under cultivation to provide adequately for an increasing population. Urban centers came into existence, sometimes far from the streams to which people were formerly bound, because now water for both irrigation and domestic use could be directed to distant locations when the terrain permitted.

Solely by hand labor, for beasts of burden and mechanical aids had not yet appeared on the scene, the Hohokam constructed several hundred miles of canals in the Gila and Salt River Valleys alone, and it is fair to assume that these brought tens of thousands of acres under cultivation where the plants known to the Hohokam—corn, beans, squash, and cotton—could be grown. These canals in places were 10 feet deep, and the main arteries

Figure 35.—Hohokam pottery effigy from Casa Grande National Monument, Ariz.

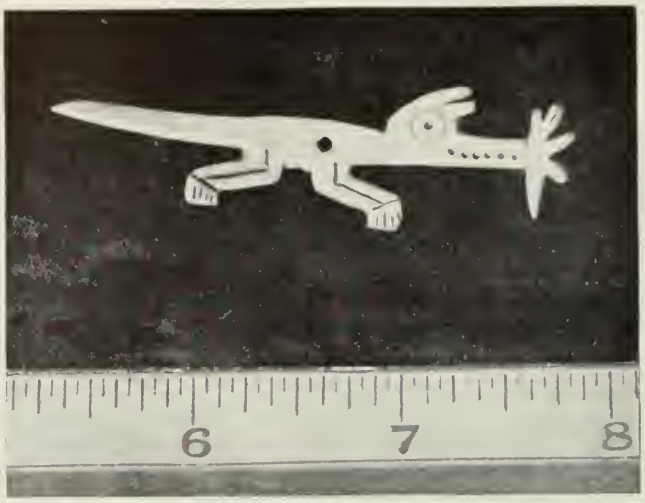

Figure 36.—Hohokam carved shell.

were from 30 to 50 feet wide, rivaling in size those of our modern systems.

One cannot see the remnants of the Hohokam canals or look at a map of the systems without being duly impressed by the prodigious expenditure of human labor that went into their construction. These systems represent possibly the greatest investment in labor put into any strictly utilitarian enterprise by the pre-Columbian Indians north of Mexico. White farmers, when they first set to reclaiming the land along the Salt River east of Phoenix, were saved many weeks of back-breaking work when they were able to recondition old canal sections and incorporate them in the new developments. We marvel today at what irrigation has done, thinking little of those trail-blazing Hohokam who more than ten centuries ago made an agricultural paradise out of the desert.

The Hohokam civilization, like all others, did not achieve its rich development in short order. Archeologists have been able to show that centuries of time were involved in the process. From the formative stage, at about the time of Christ, the culture slowly expanded its ability to extract a livelihood from the soil, and grew materially, socially, and politically. By 1000 A.D. the pinnacle of progress had been reached. This was enjoyed for perhaps four centuries, until about 1400, when the record of their society becomes dim and eventually almost lost. The causes for the decline and what happened to the Hohokam are fields for interesting speculation. As yet, we cannot supply any satisfying answers.

The dissolution does not appear to have been

rapid. This suggests the possibility that the Hohokam were unable to cope with situations affecting the very basis of their economy, namely, agriculture. We must recognize the possibility that something went wrong with their irrigation system. Nothing would tend to disrupt urban life more completely under primitive conditions than crop failure, except perhaps an attack by hostile people, for which there is no evidence in this case. It may be that the Hohokam, with genius enough to develop irrigation systems, were not alert to the dangers of overcultivation or the sterilizing effects of alkaline water.

There are some indications that the Hohokam have survived in the form of the Pima Indians who, ever since the first Spanish contacts, have occupied the center of the Hohokam area, and who, in a dilute way, have perpetuated many of the older customs. This connection is not yet demonstrable but it is highly probable.

Nothing has been said as yet of the other chief characteristics of the Hohokam. Being agricultural, they needed permanent homes. These were never pretentious, like the many-storied stone houses of the Anasazi, but were pole, brush, and dirt structures thrown over shallow excavations in the ground and generally erected some distance apart, which made for informal and loosely arranged villages. The shape of these houses changed through time, but this essential type did not change even in the fourteenth century, persisting after the arrival of the Salado people, a Pueblo group, who joined the Hohokam on a friendly basis and lived with them. Salado houses were pueblos, structures with room joined to room above ground and sometimes several stories in height. This architectural intrusion evidently had little permanent effect, for, after the Salado withdrawal from the area, at 1400 or soon after, this building form did not survive. The widely known Casa Grande near Coolidge is an impressive monument to the architectural ability of the Saladoans, dwarfing the house-building accomplishments of the Hohokam. The circular dwellings of the modern Pima are essentially similar to Hohokam houses.

Little can be said about the physical appearance of these River Hohokam because of their custom of cremation. Throughout their entire history this

Figure 37.—Casa Grande—a monument to the architectural ability of the Saladoans—Casa Grande National Monument, Ariz.

Figure 38.—Hohokam jar from Casa Grande—made about 1100 A. D.

was the prevailing custom for disposing of the dead, and, unfortunately, the ashes and calcined bone fragments found in Hohokam burial grounds offer little on which to base judgments of an anthropological nature.

Among the arts and crafts, the Hohokam were particularly skilled in the production of a buff-colored pottery decorated with a red-brown paint. This pottery changed in style of design through the centuries but the archeologist has no difficulty in relating it to these people wherever found, as one of their most distinctive products. In stonework, they gained fame in sculpturing and carving small-scale objects. Most, if not all, of these were useful things, like slate palettes on which paints were compounded. Another material which they favored

Figure 39.—Corner of embroidered cotton blanket (Salado culture about 1350 A. D.) from Tonto National Monument, Ariz.

was marine shell imported from the Pacific Coast and the Gulf of California. This substance lent itself particularly well to the production of ornaments, bracelets, rings, pendants, and beads, by such techniques as grinding, cutting, and carving. One of the exceptional achievements along this line was decorating shell by etching with an acid, covering those areas not to be affected by some acid-resisting substance. In developing this principle the Hohokam appear to have been ahead of all other contemporary people of the world.

The Hohokam also produced many lesser items which, together with those mentioned, gave distinctive quality to their culture. We know little, however, about one class of their products—things made of wood, skin, feathers, fibers, and the like. There is abundant reason to believe that the Hohokam were highly skilled in textile weaving, using

Figure 40.—Headband—slit tapestry weave in blue and white—Salado Culture about 1350 A. D.

cotton as the base fiber, perhaps as far back as 700 A.D., but this substance, along with the other perishable materials, has not withstood the ravages of time except in a few favored spots.

Geographically, the Hohokam were located in south-central Arizona, adjacent to what is now Mexico. Of all the early southwestern tribes, they were thus most advantageously situated to establish contacts by trade or otherwise with some of the high cultures of central Mexico. A number of items of undoubted southern origin or inspiration have been found in Hohokam villages of about 1000 A.D. and later. They show that the Hohokam actually were in touch with their southern neighbors. Cast copper bells and mosaic pyrites plaques are significant examples. The ball courts, or gam-

ing areas, of the Hohokam are certainly traceable to a southern parentage. All of this adds up to the fact that the Hohokam were not only creators of culture but that they also assimilated what came to them from other peoples, provided it was something they wanted.

In dating the stages of the Hohokam development, the archeologists have been able to employ the tree-ring system only in the most indirect way. Tree-ring dating has been most successfully applied to the Anasazi Culture in favored places in the Upper Sonoran and Transition Zones because it was here that the suitable trees, used in the process, grew naturally and were used as architectural material by the natives. Trade connections between Hohokam and Anasazi are seen in the interchange of pottery. Pottery of northern origin, dated in the Anasazi area by tree-rings to periods from the sixth century to the thirteenth century, aids in reaching a conclusion as to the age of Hohokam ruins. On the basis of much evidence of this sort, the Hohokam are known to have occupied the Gila-Salt Basin from near the beginning of the Christian era to the fifteenth century.

Figure 41.—Salado breechcloth—diamond twill weave—about 1350 A. D.

An important event in the final century of this time span was the arrival of the Salado tribe from the northeast. These were a pueblo-dwelling people, and as the consequence of some far-reaching changes in the Anasazi area of the fourteenth century, they moved south and west to join ranks temporarily with the Hohokam. They introduced a new architectural form, already mentioned; the custom of extended inhumation (burial, uncremated, lying on the back); several new kinds of pottery, and other material elements; and perhaps a different social and political system, too. But the mingling of these two different tribes, as far as we can see it at this late date, was on a friendly plane of mutual assistance, underlined by the fact that during this time the canal systems appear to have reached their greatest areal development. This expansion and the increased task of maintenance must have been cooperatively achieved.

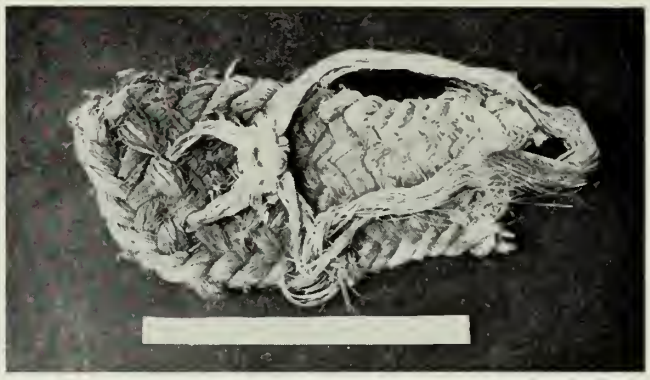

Figure 42.—Salado yucca fiber sandal.

While the main group of Hohokam along the major rivers were enjoying the security of an abundant agricultural life, related people in the desert to the south of them were living a much more precarious existence. These we may call the Desert Hohokam. Their area provided them with little surface water, least of all running streams which could be turned to irrigation. The result was an extremely limited agriculture, restricted to a few favored spots, and a much heavier reliance upon native foods which fortunately were available in the desert. The history of this branch of the Hohokam is only now being determined, but it can be said that culturally they lagged far behind their kinsmen to the north along the rivers, and that after 1400 they, too, seem to disappear from the record. Despite this gap, the modern Papago In-

dians who now occupy the same area are doubtless their descendants, just as the Pima may have been linked with the River Hohokam.

Patayan Culture.—Patayan Culture, named after a Walapai Indian term signifying " the ancient ones," is a recently recognized and still somewhat poorly defined culture. It centers along the Colorado River Valley south of Hoover Dam, radiating out from there north to the Virgin and Muddy River areas, east to the vicinity of Flagstaff, and south to the Gulf of California. Just how far it extends westward into the desert areas of eastern California is not known, although present indications are that it penetrates into the Mohave Desert region.

The existence of this culture was recently revealed through surface surveys yielding pottery types distinct from others in the Southwest. On meager archeological evidence, this culture has been divided into at least two branches, one centering on the Colorado River from Hoover Dam to Bill Williams River, and the second extending from the latter river south to the Gulf of California. To the east of the Colorado River are two other areas where Patayan influence was strong, including the region west of Flagstaff where Anasazi and Patayan Cultures met and mingled, and the area around Prescott where a number of complexes occur.

Of these various branches the Cerbat group, that extending along the Colorado River north and south of Needles and eastward for 50 or more miles, is believed to represent the purest Patayan Culture. Although several related sites have been excavated to the eastward, so far no site in the Cerbat area has been excavated. Thus, our knowledge of this important basic culture is limited almost entirely to what information has been secured from surface surveys. These surveys have shown that occupation of this central area was relatively heavy in prehistoric times, as well over 300 Patayan sites have now been located.

Due to our lack of adequate information, the reconstruction of the prehistory of this area is largely based on conjecture. However, it seems evident that about 1500 years ago groups of hunters and seed gatherers, possibly nomadic Yuman-speaking peoples, diffused into the Colorado River Valley from southern California. There they soon came in contact with outlying groups of the already established southwestern cultures, the Hohokam in the south and the Anasazi to the north. Within a short time these nomadic groups took up agriculture and pottery making and began to develop a distinctive culture of their own.

From a study of the materials recovered from the surface surveys we can give a fairly accurate picture of the life of these peoples. In contrast to the Upper Colorado River, where narrow and deep canyons prevented large villages and agricultural fields, occupation here was heaviest along the Colorado River itself. About 20 miles below Hoover Dam the valley widens out, with extensive sandy flats where agriculture could be practiced by planting in areas left moist through the retreat of the annual spring floods. Due to these floods, however, evidences of habitations on the flood plains are infrequent, the houses having been either washed away or buried beneath layers of mud and sand.

Houses probably consisted of circular brush and mud shelters or earth lodges, temporary shelters at best. Agriculture was extensively practiced, corn, beans, squash, and cotton being raised. The ceramic remains consist of sherds of pottery shaped by the use of paddle and anvil as contrasted to the coiled and scraped technique of the Anasazi. This paddle and anvil technique was probably derived from the Hohokam area. Patayan pottery is usually reddish, buff, brown, or greyish-brown, some types showing a glazed or crusted surface. Although much of the pottery is plain, simple decoration was sometimes applied in red or black. Stone implements included mortars and metates, arrow points, scrapers, choppers, knives, pottery anvils, and hammerstones. It is quite likely that these Indians cremated their dead.

Through the presence of intrusive black-on-white pottery types traded in from northern and northeastern Arizona, types that have been accurately dated by means of tree-ring studies, it is evident that this Patayan Culture flourished from about 700 to 1100 or 1200 A.D. Whether these Indians left the Colorado Valley after 1200 or whether they remained is not definitely known. We do know that when the first white explorers arrived in the area during the sixteenth century they found a number of closely related Indian tribes occupy-

ing the entire valley. Furthermore, these Yuman-speaking people possessed a culture strikingly like that of the earlier Patayan people. These Yumans practiced agriculture in much the same way, raising the same products, lived in domed brush and mud houses along the banks of the river, made similar reddish-brown pottery vessels, and cremated their dead.

Linguistic evidence divides the Yuman peoples into two branches, the Delta and River groups, a division which is shown by archeological research to have also existed in prehistoric times. During the historic period, the Hopi Indians of northern Arizona carried on extensive trade relations with the Mohave Indians of the Colorado River. That these trade routes were utilized in earlier times is shown by the presence of late prehistoric Hopi pottery of fourteenth century and later types in sites along the Colorado River and westward in the Mohave Desert area. From all of these indications it is highly probable that the modern Mohave and Yuma Indian tribes represent the descendants of the earlier Patayan people. However, this question cannot be definitely answered until a number of Patayan sites have been carefully excavated and thoroughly studied. The sites are small and inconspicuous, since there are no standing remains of permanently built houses.

Anasazi Culture.—North and northeast of the Hohokam and Mogollon domains is the vast and rugged area which was home to the people known as the Anasazi, the ancient people, so called by the Navajo Indians who settled among the ruined villages of this culture several hundred years ago. The land appears incapable of supporting the sizeable prehistoric population indicated by the countless thousands of ruins dotting the plateau. However, the present cycle of degradation, or arroyo-cutting, and the consequent lowering of the water table, is largely of modern origin, materially aided by overgrazing since about 1880. Formerly, within the memory of living persons, numerous tree-lined streams occurred over the plateau country, with grass thickly covering the surrounding valleys. Segie Canyon in northern Arizona illustrates this quite well. Less than 100 years ago the broad valley floor was covered with grass and trees

Figure 43.—Pueblo Bonito—Chaco Canyon National Monument, N. Mex.

and dotted with numerous lakes and lagoons. Today the soil is barren and a deep, broad wash extends nearly from wall to wall of the canyon. Thus, keeping in view the former picture of this region, it is readily seen why prehistoric man settled here and how he was able to live so abundantly off the land for centuries.

Our first definite knowledge of the oldest settlers of this Anasazi area comes about the opening of the Christian Era. It is generally thought that early nomadic occupants of the plateau obtained corn and the knowledge of how to plant and cultivate it from the groups to the south, probably from people of the Mogollon Culture. The earliest known "Basketmakers" had corn. Although agriculture was practiced by these people, wild vegetable products and wild animals were still extensively utilized. With the change to a more sedentary existence, it soon became necessary to provide storage places for surplus corn. Dry caves were used for the construction of circular or oval pits, often slab-lined, with earth-covered pole and brush superstructures. These storage cists were frequently put to a secondary use, serving as burial chambers; and, since material objects used in life were usually placed with the deceased, we derive a considerable amount of information of the people and period from a study of articles found in the caves.

These people were skilled makers of coiled baskets, often decorated in color, twined-woven bags, fur-cloth robes, sandals with toe fringes and human hair cord ties, rope, head bands, snares, large game nets, and stone and shell ornaments. Weapons included the throwing stick or atlatl, curved, grooved wooden clubs, and elk antler clubs. These people lacked, however, the bow and arrow, fired pottery, and the hafted ax.

Although this Basketmaker Culture, so-called because of the great abundance of coiled baskets found in the caves, reached its highest development in the San Juan drainage in southern Utah and northern Arizona, it extended over practically the entire Anasazi area. One of the most important early Basketmaker sites yet found is Dupont Cave, near Kanab, Utah, a cave which was dated by means of tree rings as showing a Basketmaker occupation as early as 217 A.D.

In the fifth century, fired pottery was developed,

Figure 44.—Check dams built by the Anasazi at Mesa Verde National Park, Colo.

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possibly from ideas brought in from the Mogollon people. We have also the first beginnings of architecture at this time, with the construction of circular, oval, or rectangular pit houses, some in caves, mostly in the open valleys and on mesa tops. Other new elements and ideas coming in include the bow and arrow, the grooved stone ax, the cultivation of beans, domestication of the turkey, and widespread use of turquoise for ornaments.

From these Basketmakers there eventually emerged by the eighth century a somewhat different culture type, the Pueblo, the result of evolution of culture and probably of the adoption of new cultural elements from outside and perhaps intermingling with new peoples. Cotton was introduced, and fabrics made from it soon assumed an important place in the daily life of the people. Other innovations included improvements in pottery making, neck-banded utility vessels, twilled-woven sandals and baskets, and the development of the kiva or underground ceremonial room.

Within a short time houses changed from single-room, semi-subterranean dwellings to above-ground structures with masonry walls, until by 1100 A.D. great multistoried communal dwellings of several hundred rooms were being constructed. These large apartment houses were built both in caves—the cliff dwellings—and in the valleys, and their ruins may still be seen today at such sites as Cliff Palace, Pueblo Bonito, Wupatki, and Walnut Canyon. Specialization rapidly took place in the various arts and industries, the apex of development in the San Juan area being reached between 1000 and 1300 A.D. Pottery making became a highly specialized art, with very elaborate black-on-white decoration and the evolution of several polychrome types and of corrugated wares.

Since agriculture was the principal occupation of these prehistoric pueblo people, their communities are largely to be found concentrated along the streams and rivers where water and arable land could be utilized for the fields of corn, beans, squash, and cotton. Nature was against elaborate irrigation systems of the Hohokam type, but it did supply a more bountiful rainfall than in the desert. However, in some cases, at least in this northern country, as in the Muddy River Valley in Nevada, it is evident that ditch and canal irrigation was practiced to a limited extent. The shortage of rich bottom lands

Figure 45.—Anasazi basket quiver (made about 1200 A. D.) from Canyon de Chelly, Ariz.

in the mountain valleys was partially offset by laying up rows of rocks along the contours on mesa tops as well as in the valleys. This stonework spread out the moisture which fell as rain, putting it where it would do the most good and preventing much of it from running off and thus being lost. Small check dams of rock built across arroyos are sometimes associated with this form of contour terracing, an obvious attempt to check the run-off. A study of many of these ruins will show how carefully sites for fields were selected so that full advantage could be taken of the surface run-off from higher ground. Since both flowing water and rainfall were limited over most of this southwestern country, these early pioneers utilized what little they had to the fullest extent.

One of the best areas where these aboriginal efforts at conservation and intense cultivation of seemingly useless land may be seen is in the eastern part of the San Carlos Indian Reservation along the northern flank of the Natanes Plateau. Here hundreds of acres were terraced and farmed between about 1000 and 1400 A.D. Centuries later, in the 1930's, the Civilian Conservation Corps used essentially the same system to check erosion and aid in re-establishing the vegetation in denuded areas.

The Pueblo Indians, however, did not use the main Colorado River Valley as much as they did the smaller tributaries of the Colorado. From Marble Canyon south and west throughout the entire length of the Grand Canyon, sheer walls rise almost directly from the river's edge, and there was little available land on which agriculture could be carried on. Also, the tremendous floods during the

late spring and summer would periodically wipe out their fields. Thus the canyon served mainly as a hunting and seed-gathering area for these people, and most of the archeological sites within the canyon itself are those of small temporary camps on gravel benches or in small caves.

In an area that is today noted for its thousands of mines, it is interesting to record that the first mining was carried on as early as twelve to fifteen hundred years ago. However, it was not for gold or silver or other minerals we so eagerly search for today that these early miners dug. They were interested chiefly in rock salt, turquoise, and such paint materials as hematite and limonite. Numerous salt mines have been found along the banks of the Verde and Virgin Rivers, both open pit mines and natural caves being utilized. Turquoise pit mines near Hoover Dam contain pueblo potsherds and stone picks and hammers. Production of surplus quantities of turquoise and salt enabled extensive bartering to be carried on with other areas. A number of regular trade routes have been traced over the region. That the turquoise industry was an important one long before the discovery of America is shown by the hundreds of thousands of turquoise beads and products found in the ruins of the Southwest. As many as 30,000 beads have been found in one room of Pueblo Bonito in Chaco Canyon National Monument, N. Mex.

An unusual phase of the ceremonial life of these pueblo people may be inferred from the many petroglyphs which occur throughout the area. These figures, pecked with small hand stones on large rocks or on smooth cliff walls, present a wide variety of geometric and naturalistic designs, including circles, scrolls, wavy lines, and human and animal forms such as snakes, lizards, turtles, mountain sheep, and deer. Petroglyphs are found in every section of the basin, but they vary from area to area and from culture to culture. They can seldom be interpreted, although many undoubtedly represent such things as ceremonial symbols, good-luck charms, clan symbols, and direction markings.

Since populations were concentrated in river valleys adjacent to an adequate water supply, and since each drainage area was set off from neighbor-

Figure 46.—White House Ruin—Canyon de Chelly National Monument.

ing ones either by mountain ranges or by intervening regions lacking water, there gradually arose distinct culture units in each of these drainage areas. Distinctions are frequently found in pottery, particularly in tempering materials, vessel shapes, and styles of decoration, and, to a lesser extent, in architecture and other elements of culture. During the height of the Pueblo Culture, from about 1050 to 1300 A.D., distinct culture areas are noted in the Kayenta region, Mesa Verde, Chaco Canyon, Little Colorado River Valley, Flagstaff, the Kanab area north of the Colorado, the Upper Virgin, and the Lower Virgin. While most of these areas present relatively pure Anasazi Culture, in several areas there was a decided overlapping of cultures. In the Lower Virgin area there is a blending of the Anasazi and Patayan, typified in such pueblos as Mesa House and Pueblo Grande de Nevada. In the San Francisco Mountain region around Flagstaff, there is a blending of Anasazi and Mogollon, together with numerous elements of the Hohokam and Patayan Cultures.

During the latter part of the thirteenth century the entire northern Anasazi area was abandoned, the people from the eastern San Juan moving into the Rio Grande Valley and those from the western area pushing south and southeast into the Little Colorado drainage and the mountains of eastern Arizona. No definite cause for this abandonment is known. However, from tree-ring studies we know that the Southwest suffered a severe drought during the period from 1276 to 1299 A.D. As a result of this drought there would inevitably be numerous crop failures and also the supply of wild seeds and even wild game would be limited. Arroyo cutting and lowering of the water table may well have been contributing factors. This, together with the possible incoming of numbers of nomadic invaders, such as the ancestors of the present day Navajo, Apache, Ute, and Paiute, encroaching upon Pueblo lands and plundering their villages, undoubtedly led the Pueblo people into larger communities in areas where permanent water occurred.

One of the significant trends, evident in examining the archeology of east-central Arizona, is the shifting frontiers of the Pueblos. This moved progressively farther south and west with time, culminating in the fourteenth century with the Salado

Figure 47.—Wupatki Ruin in Wupatki National Monument, Ariz.

migration which overran the Hohokam territory. The main reason for the earlier southward drift is the fact that the Anasazi, accustomed to a plateau environment, could keep to the same physical surroundings almost as far south as the Gila River. One of the best examples of this is the Natanes Plateau south of Black River where there was a great concentration of Anasazi.

The largest individual settlements on the Mogollon Plateau and in the coutry south of the Mogollon Rim on the upper reaches of the Salt River date from the thirteenth and fourteenth centuries, a period which also marks the time of the highest cultural achievements. Many of these are found in the environs of the White Mountains of eastern Arizona, one of the most densely populated areas of late prehistoric time. This coincides more or less with the shrinking of the northern frontiers of the tribal range and, as already mentioned, may be linked with either a period of climatic instability, the arrival of unfriendly nomadic peoples, or a combination of both. This late upsurge of population, with consequent introduction of new ideas, is shown by the construction of very large pueblos and the development of new pottery types, particularly polychrome wares. Glaze paint was developed late in the thirteenth century and was widely utilized. Black-on-white and corrugated types of pottery gradually disappeared during this period.

Figure 48.—Montezuma Castle in Montezuma Castle National Monument, Ariz.

The Anasazi (Pueblo) occupation of the White Mountain region ceased about 1400, a century or more later than was the case for the San Juan Basin and about the same time that we noted the withdrawal of the Saladoans from the Hohokam country. This was indeed a period of unbalance over much of the Southwest, the reasons for which are not yet clear. But in the White Mountain area there are more indications that the newly arrived Apache Indians may have had something to do with the upheaval.

At all events, the frontiers of the Pueblos continued to shrink during the following century, with a gradual withdrawal into the drainage of the Little Colorado River. Here for the first time we encounter the modern inhabited pueblos of the Hopi and Zuni Indians, the Hopi living on three mesas a short distance north of the Little Colorado, the Zuni on the upper reaches of the Zuni River in western New Mexico. In this general area we also find abandoned towns of these same people of the early historic period and numerous prehistoric settlements through which the ancestral lines of these tribes may be traced. In 1540, when the first Spanish conquerors arrived in the Southwest, they found the descendants of these prehistoric Indians concentrated in about 13 pueblos in the Hopi and Zuni areas in the Colorado River Basin, and about 60 in the Rio Grande drainage to the east.

It is in the drainage of the Little Colorado that the setting is at its best for achieving the aims of archeology, for following the history of the Pueblo Indians, determining how they adjusted themselves to their environment, with whom they were in contact, how they spread, and what they accomplished. It is in the ruins of this region that nearly two thousand years of continuous Pueblo history may be read. It is here, too, that the agricultural practices of the Hopi and Zuni, little changed from those of a thousand years ago, may be studied to gain a clearer insight of how man, without our present vaunted knowledge of plant culture and without domesticated beasts of burden, was able to achieve a measure of security.

The Northern Periphery.—To the north of the Anasazi area lies an extensive region called the Northern Periphery, largely because it is related to the main southwestern area and because not too much is known concerning the prehistory of the region to warrant giving a more descriptive name to the culture or cultures found there. Future work will, no doubt, furnish us with more accurate and detailed information so that various cultures and sub-cultures will be recognized.

This area, comprising the headwaters of the Colorado and Green Rivers in northeastern Utah, northwestern Colorado, and southwestern Wyoming, covers the extreme northern portion of the Colorado Plateau, with generally high terrain cut by numerous deep canyons and washes and culminating in high ranges that tended to form cultural barriers. In an area such as this there were relatively few opportunities for the practice of agriculture, which was confined mainly to a number of the smaller tributaries of the Colorado and Green Rivers. With such meager opportunities for the cultivation of crops on a large scale, there was a definite limit imposed on the size to which villages could grow. Consequently, the majority of archeological sites in this region are quite small, seldom exceeding 10 to 15 rooms.

Archeologically, this Northern Periphery is characterized by a progressive fading of the basic Anasazi Culture pattern in proportion to the distance from the San Juan area. While the essential features of this northern culture are clearly derived from the Southwest, particularly from the Anasazi area, the cultural core cannot be directly correlated with the Basketmaker-Pueblo periods of the south.

As mentioned previously, our knowledge of the prehistory of this area is scanty. Although a considerable amount of surface survey work has been carried on in many parts of the region, actual excavation has been limited in amount and restricted to a few localities. Thus, the following brief comments are largely based on field work in only small sections of this vast plateau country.

Seemingly about a thousand years ago or more a knowledge of agriculture and pottery making filtered through this area from the San Juan region. These elements, together with others, were soon taken over by the nomadic peoples occupying the area and the foundations were shortly laid for a well-integrated culture. Information is lacking on these earlier nomadic hunters and seed gatherers and we can only assume their former presence over much of the area.

The first definite culture we can delineate represents a blend of late Basketmakers and early Pueblo elements from the San Juan. It seems probable that most of the Northern Periphery never received to any great extent classical Basketmaker Culture as found to the south but only a mixture of Basketmaker and Pueblo. Thus, while this early culture is basically Basketmaker in pottery, there are enough early Pueblo elements, as well as some traits of local origin, to indicate an entirely different cultural picture than that in the Anasazi area. Certain parts of the area also reflect influences from the plains area to the east and northeast and from the great basin region across the mountains to the west.

The basis for this complex was agriculture, corn, beans, and squash being cultivated wherever possible. This was, however, only a semi-sedentary culture, as the people still relied extensively upon hunting and seed gathering. This is indicated by the great number of arrow points, grooved arrow shaft smoothers, and horn arrow wrenches found in practically all sites of this period. The extensive use of coiled basketry similar to that made by the Basketmakers also tends to show strong reliance upon the gathering of wild seeds.

Villages were quite small and consisted of a series of shallow pit structures or earth lodges, in many respects like Basketmaker houses, with adjoining slab-lined storage cists. Excavations in the Uinta Basin and adjacent areas have yielded information about these dwellings. Of the elements of material culture, plain gray Basketmaker pottery is most typical in the northern area, with the addition of a limited amount of early Pueblo black-on-white ware. Other features of this culture include fur and feather cloth, tubular stone pipes, twined bags, and the bow and arrow.

At a somewhat later date the introduction of new elements and ideas from the southern pueblo region marked the opening of the second and final phase of this prehistoric northern culture. This period is characterized by a greater dependence upon agriculture, with the consequent construction of larger, more permanent villages. Formal archi-

Figure 49.—Betatakin Ruin—Navajo National Monument, Ariz.

tecture was introduced and rectangular masonry houses were built, with associated masonry granaries. Extensive use was made of caves throughout the area, numerous masonry granaries and houses occurring in these caves. Corrugated pottery was also added to the complex and greater use made of more elaborately decorated black-on-white pottery.

It is evident from the foregoing that, in general, this culture is largely a southern complex which has moved northward. However, it lacked such distinctive Anasazi traits as domesticated cotton, the loom, the domestication of the turkey, twilled ring baskets, grooved stone axes and mauls, and such pottery forms as canteens, pitchers, ladles, and highly decorated wares. In addition, a number of other elements point either to a considerable admixture of ideas and features from other neighboring areas or to purely local developments.

These occur particularly in the Fremont River drainage west of the Colorado River and include such traits as black-on-grey pottery, highly ornamented clay figurines, a distinctive style of moccasin, and an abundance of elaborate petroglyphs. The petroglyphs represent one of the most striking and characteristic elements of the Northern Periphery, being found in profusion over the greater part of the area. Anthropomorphic figures are especially common, as well as large human figures with elaborate headdresses, geometric designs, deer, and mountain sheep. Many of these seem to have been derived from Basketmaker prototypes, as the triangular-bodied figures, but in this region the art has been greatly developed and elaborated over anything found to the south. Perhaps the highest development of the petroglyph art occurs in the western and northern sections of the area in the Uinta Basin and Nine Mile Canyon.

Just what happened to this culture we do not know. About 1000 A.D., or shortly thereafter there was a gradual shrinking of the inhabited area, the northern sites being the first to be abandoned. The general lack of classic Pueblo materials demonstrates that this cultural occupation came to an end before the period of highest development in the San Juan region. The strategic location of many sites in the Northern Periphery, such as forts, suggests that these people were subjected to pressure, possibly by hostile nomadic groups, at a relatively

Figure 50.—Modern Indian Zuni Pueblo, N. Mex.

early date. If, as stated in a previous section, we postulated nomadic groups from the north as being a deciding factor in causing the abandonment of the San Juan region during the latter part of the thirteenth century, such pressure would have occurred still earlier in the areas to the north. Furthermore, the general precariousness of farming in this area may also have influenced the abandonment. All that can definitely be said is that after approximately 1100 A.D. we completely lose sight of these people. Where they went can only be conjectured. For the past several hundred years the nomadic Utes have been occupying a large part of the region.

MODERN INDIAN TRIBES

Although archeology is primarily concerned with the study of prehistoric peoples, one phase of this study lies in endeavoring to link these early peoples with the modern. Thus, the location, extent, and cultural achievements of present-day Indian tribes in this area are likewise of deep interest to the student of human history and efforts are made to trace these cultures back into the past.

At the present time at least 15 different Indian tribes, representing five or more distinct linguistic groups, occupy various sections of the Colorado River Basin. From all indications most of these tribes have been in the area for hundreds of years, since the earliest Spanish records, dating back to the sixteenth century, show that members of practically all of these groups were encountered in the same general regions in which they are found today.

In northern Arizona and western New Mexico the Hopi and Zuni Pueblo Indians still occupy villages in areas they and their ancestors, the prehistoric Indians who built cliff dwellings and multistoried mesa pueblos, have inhabited for almost the past 2,000 years. The same can be said for the Pima and Papago Indian tribes living today in the valleys of southern Arizona, tribes that are in all probability the descendants of the prehistoric Hohokam desert dwellers. Along the Lower Colorado River and its tributaries, in the territory formerly the seat of the Patayan Culture, occur the scattered remnants of the Yuman tribes, the Havasupai, Hualpai, Yavapai, Mohave, Maricopa, Yuma, and Cocopa, tribes that may be in part the living representatives of the prehistoric river peoples.

The various foregoing modern Indian tribes all fall into the same general classification of sedentary peoples. To a greater or less degree all these groups are agriculturists, live in permanent villages, make pottery in abundance, and are skilled in the arts and crafts. Thus, the task of tracing their historic and prehistoric remains throughout the region is considerably simplified.

However, turning our attention now to the present-day nomadic hunting and seed-gathering tribes —tribes that, strictly speaking, were not sedentary, were not agriculturists, and made relatively little pottery—efforts at tracing these peoples back into the past are infinitely more difficult. Archeological remains of these groups are very sparse and, consequently, much of their early history can only be postulated. It seems likely that, perhaps during the thirteenth century, bands of Athapascan-speaking peoples entered the Southwest, from the western plains or through the Great Basin, having come originally from western Canada where today dwell the main body of Athapascans. These bands spread in various directions over the Southwest and, after receiving accretions from the Pueblo peoples and others, eventually became the modern Navajo of northern Arizona and New Mexico and the Apaches of eastern Arizona. These two tribes were mainly hunters and fighters, and agriculture and pottery making were only incidental features of their culture, developed after arrival in the Southwest under Pueblo influence.

Our knowledge of the prehistory of the last of the nomadic tribes within the area—the Ute of western Colorado and Utah, and the Paiute of southern Utah and eastern Nevada — is limited. Relatives of these tribes have been in adjacent areas in the Great Basin for centuries, and it is highly probable that these two groups entered the Colorado River Basin at some remote time during the prehistoric period.

It is evident from the foregoing that a great deal of work remains to be accomplished on the study of these modern Indian tribes, particularly the various nomadic groups, before the essential framework of their cultural past is clearly defined. Villages and camp sites of the historic period, that is, since 1540

A.D., connect the modern tribes, which are historically and ethnologically known, with the prehistoric ruins. Future study of such sites will serve both to determine the origins and relationships of the living tribes and, conversely, to animate and illumine the prehistoric ruins and artifacts, to fill out the incomplete picture they present of aboriginal cultures and peoples. Such sites, numerous in the Colorado drainage though relatively little-studied so far, range from large pueblos such as Awatovi, destroyed in 1700 A.D., and almost deserted Oraibi, to inconspicuous camping places of Ute hunters.

SIGNIFICANCE OF ARCHEOLOGY

Archeology is of significance not alone to the archeologist or student of primitive man. Archeology, in brief, is the study of human history. The more we learn about the life and times of every ancient people and tribe, the more we learn concerning the rise and fall of past human civilizations, the more we learn of how other people at other times attempted to solve various situations, the better equipped we shall be to solve our present and future problems of individual and social adjustments.

Archeology as a science can be justified solely on the basis that people are interested in it and desire to know more about it. A review of the feature stories of the past few decades will reveal that a number of them deal with spectacular finds of archeological material, such as the opening of King Tut's tomb in Egypt, the jewelry from Monte Alban in Mexico, the jade ornaments and giant stone heads from Vera Cruz, and the still romantic cliff dwellings of the Southwest. The old saying, "The proper study of mankind is man," is still as true as the day it was first spoken.

One of the greatest assets of archeology lies in the field of popular education. Our local, State, and national museums derive a great deal of their exhibited material from archeological excavations. The specimens and information resulting from these excavations increase our knowledge of the historical background of the Colorado River Basin. Archeology will also furnish our scientists with much valuable information on past climatic changes, population trends and migrations, methods of agriculture, problems of land use, and many other beneficial phases vital to our present civilization.

The National Park Service, through its national parks and monuments, has preserved for study and public use a great many of the outstanding archeological ruins in the Colorado River Basin. Some of the most important of these, to name only a few, are thus protected in Mesa Verde National Park, in Dinosaur, Navajo, Canyon de Chelly, Wupatki, Chaco Canyon, Aztec Ruins, Casa Grande, and Tonto National Monuments, and in Lake Mead Recreational Area. However, there are literally thousands of other ruins, many of which are equally important, which do not have this protection and are consequently subject to destruction through any one of a number of causes.

EFFECT OF RESERVOIRS ON ARCHEOLOGICAL REMAINS

The greater part of the archeological wealth of the Southwest, as is evident from the foregoing discussion, is found within the Colorado River Basin, and a considerable part is concentrated in the valleys themselves adjacent to an adequate water supply and agricultural fields. Construction of dams and the consequent flooding of hundreds of miles of river valleys will destroy countless thousands of these prehistoric and historic ruins. This archeological heritage, including house remains, pottery, stone, bone, and shell ornaments, implements, and utensils, burials, and other materials forms a national asset, a priceless record of prehistoric man's aims and accomplishments that can never be replaced, once the evidence is destroyed. The sites and artifacts represent a span of thousands of years, from the ancient hunters of animals, now extinct, to the historic tribes of living Indians.

In the course of modern reclamation and power development, it is inevitable that ruins of major archeological value in the Colorado River Basin will be destroyed. These ruins can be grouped into three general classes: (a) those which lie within the actual reservoir area of a dam site and will thus be flooded, (b) those which lie below the reservoirs on cultivable land to be put under the plough by

virtue of the availability of a new and constant water supply from the reservoir; and (c) those which lie in the path of canal, road, or other construction related to the project as a whole.

RECOMMENDED PROGRAM

To offset this potential loss of the vestiges of early Americans, a loss which will be irretrievable to the scientist and the public alike, there is a definite and immediate need for a well-planned and coordinated archeological program for the Colorado River Basin, a program that will include specific recovery measures. This program might well be in accord with the resolution proposed by the Committee for the Recovery of Archeological Remains for the conservation of national archeological resources in the various river valleys, and should include the following provisions:

1. A careful archeological survey, carried out by trained personnel, of each of the prospective dam sites, both above the dam within the reservoir area and below the dam where ruins may fall within construction or land reclamation limits. This preliminary reconnaissance is to be done well in advance of construction time, and will include specific recommendations as to the nature of archeological work required.

The Preliminary Archeological Survey and Recommendation for the Davis Dam Reservoir Area, prepared by the National Park Service, May 1943, as a part of the survey of the Recreational Resources of the Colorado River Basin, is a specific example of the type of survey and recommendations needed. This survey located and mapped 150 archeological sites within the reservoir area and indicated that 15 of them were of sufficient importance to be tested and at least partially excavated prior to the filling of the reservoir. Of the 15 important sites, at least 7 should be thoroughly explored.

A survey was also made on the Yampa and Green Rivers in the Juniper, Echo Park, and Split Mountain Reservoir sites. About 20 archeological sites were definitely located and evidence of other sites was found. A number of these sites, particularly the cave and rock-shelter sites and a larger surface location, should be thoroughly explored before they are inundated.

2. Excavation of sites selected on the basis of their special importance as determined by the archeological survey. The recovery program must be begun early enough to avoid work stoppages before projects have been completed by the rising waters impounded behind the dam. Finally, the work should be done by qualified archeologists cooperating closely with both State and Federal agencies. Pursuant to an inter-bureau agreement with the National Park Service, investigation and salvage of archeological remains in connection with the Bureau of Reclamation and Corps of Engineers water-control projects throughout the United States are being conducted under the direction of the Smithsonian Institution.

3. Thorough laboratory study and adequate publication of the scientific data.

In summary, since a high percentage of the archeological remains of the Colorado River Basin are confined to the various river valleys, in areas where they are subject to potential destruction by the construction of proposed dams, it is highly imperative that funds be made available and a definite program along the lines just suggested be immediately initiated, in order to recover the important data and material from key sites before their inundation.

CHAPTER V

Factors Determining The Recreational Benefits of Reservoirs

LOCATION

In the Colorado River Basin, where few lakes occur naturally, the creation of large water bodies is of great recreational importance. This is especially true in the large, arid, lower portions of the basin. The higher portions of the basin are fairly well supplied with clear, year-round streams and attractive small lakes. Here reservoirs play a much less important role in the general recreation picture.

On the whole, a reservoir on a mountain stream will be of less benefit for fishing than one on a lowland stream, at least in the Colorado River Basin, and may be seriously detrimental to fishing. One reason for this is that the mountain streams usually are silt-free, and provide a fair-to-excellent habitat for fish even before construction of the reservoir. Another reason is that in the Colorado River Basin the majority of the potential mountain reservoirs as now planned will have a large drawdown. Thus, fluctuating shore lines, with their drastic curtailment of aquatic food production, are substituted for the relative stability of the original mountain stream condition.

As will be shown, the potential productivity of a reservoir is rather closely limited to the area of shallow bottom that is kept at a favorable depth for plants, rather than by mere volume of water. The productive area of a proposed deep reservoir usually will occur only along the shallow margins, whereas the productive area of the mountain stream that it is to replace usually comprises the entire stream bed from bank to bank. Extreme examples occur, particularly in Colorado, wherein existing fish production and extremely important attendant recreational values on various beautiful mountain streams would be jeopardized by the substitution of relatively barren reservoirs with bleak, fluctuating shore lines. One of the best of such examples is afforded by the Gunnison River, which is one of the finest natural trout fishing streams in the United States. Reservoirs on the upper reaches of this river and its major tributaries would, in most cases, destroy more recreational values than they could supply. On the other hand, reservoirs near the headwaters of these tributaries sometimes bring an increase in production and furnish good fishing, as in the case of the Taylor Park Reservoir near the upper end of the Taylor River. In this case, improvement may have resulted from the substitution of a large body of water with extensive, shallow shore lines for a previously existing small streamway. It illustrates again the need of estimating the effects of each proposed reservoir separately.

Reservoirs in national forest primitive areas and other high mountain country usually add little if anything to the general recreational value of the area and frequently destroy more than they create. They alter natural conditions just as do roads and other facilities. Construction of the dam requires roads for the transportation of men, materials, and machinery. Aggregate or fill for the dam is usually obtained as near as possible to the dam site, eliminating a piece of wilderness. Stock piles and construction camps take more. Tunnels and canals for transporting the water from the reservoir to the area of use further spreads the effects of the project. The cuts and fills required for highline canals on mountainsides are frequently visible for long distances. This is not all. The mere fact that these works exist eliminates the important intangible value of an area undisturbed by works of man.

There are a number of instances in the Colorado Basin where the economy of the nearby communities is dependent to a large degree on the income from fishermen and vacationists attracted to the region from considerable distances. If the rarer trout stream fishing is replaced by the more com-

mon and widespread reservoir fishing, it is likely that the attraction of these regions will be considerably less.

Converting natural lakes into reservoirs.—In the Colorado River Basin, the enlargement and conversion of a natural lake into a reservoir rarely, if ever, will increase biological productivity and benefit fishing or related recreation. Raising the level of the lake obviously is for the purpose of using the additional water, which means that a considerable fluctuation will take the place of the former stability. The additional volume of water will not bring a corresponding increase in productivity. Only the addition of permanent, nonfluctuating, shallow water can do this. The prospect of such a loss of original productivity and recreational value, without any corresponding recreational gain, is illustrated by a plan, subsequently abandoned, to dam beautiful San Cristobal Lake on the upper reaches of Lake Fork of the Gunnison River.

Reservoirs in arid regions.—More often in the Colorado River Basin the creation of a lake will introduce recreational activities and be of distinct value to the district. Many of the reservoir sites are in arid regions where water is a welcome sight and, though some of the reservoirs may not be ideal for recreational use, they will still have some recreational value. Frequently the water area will provide an opportunity for a number of new enterprises such as cabin camps, boat equipment, supply and storage, fishing supplies, and refreshment establishments.

The construction of a large reservoir on a desert stream profoundly alters the immediate environment, and often improves it greatly for fish and some other kinds of wildlife. This is particularly true if the stream above the lake is heavily silt-laden. Water entering the lake loses its velocity sufficiently to deposit this silt. Productivity of the resulting clear water in a warm environment of high light intensity may be increased a thousandfold, depending upon the degree of water-level fluctuation.

The improvement in the environment resulting from reservoir construction on a desert stream is not limited to the lake itself, and may be even greater in a section of the stream below the lake. The Colorado River, for a 50-mile stretch below Lake Mead, affords an excellent example of this kind of improvement. Water discharged from the lower levels of this deep reservoir ranges approximately between 54° and 61°F.,[1] whereas temperatures for the undammed Colorado River at Yuma range between 40° and 90°F., with the normal variations perhaps 10° F. less extensive than this.[2] Violent churning of the water as it passes into the open air from the turbine outlet of the dam renews the high oxygen content. The silt-free water flows for 50 miles or more over clean gravel shoals that are covered by an almost continuous blanket of green algae.[3]

Growth of such bottom plants in the intense light is rapid, and is uninterrupted because the absence of a severe winter climate permits water temperatures to remain fairly constant throughout the year. The result is that fish-food organisms also multiply enormously and continually. Trout, which normally could not exist within scores or hundreds of miles of this stretch of river, have been introduced with great success. They grow rapidly and so uniformly that the age determinations on the basis of growth rings on scales have been futile.[4]

Reservoir construction on desert streams can be of great benefit to recreation when, as in the case of Lake Mead, it substitutes a large, clear lake suitable for warm-water game fish, together with a section of Transition Zone trout stream, for the previous turbulent, silt-laden, and unproductive river waters.

By contrast, Lake Havasu, a municipal water-supply reservoir 112 miles below Lake Mead, is far less productive of fish and other aquatic life because of the difference in its construction and functions. Although the reservoir is 42 miles long, the dam raises the water level only 75 feet at maximum, and the discharge occurs at only 50 feet below this extreme high-water line. For this reason, the stream below the dam, though silt free, is but little cooler in summer than the undammed river and therefore is unsuitable for trout, though favorable for warm-water fish.[5]

[1] Moffett, *loc. cit.*, p. 77.
[2] Dill, *op. cit.*, p. 130.
[3] Moffett, *loc. cit.*, p. 79.
[4] Moffett, *loc. cit.*, p. 83.
[5] Dill, *op. cit.*, p. 112.

Still more in contrast to the deep, relatively stable power reservoirs, are most irrigation reservoirs, wherein the maximum drawdown usually occurs in the middle of the growing season for aquatic plants. The amount of drawdown may depend on year-to-year variations in rainfall and in the resulting storage capacity, and therefore may be less excessive during the wetter years. Nevertheless, the general operational cycle of irrigation reservoirs usually is characterized by far greater extremes of fluctuation than is the case with power reservoirs. Production of plant and animal life, therefore, is far from stable, while in extreme cases, which unfortunately are numerous, water levels drop so far that the reservoirs are biological deserts.

Convenience of access is an important factor in determining the value of an area for recreational use. Reservoirs on or near high-standard roads are likely to receive a much larger use than those reached by mountainous, narrow, rough, sandy, or otherwise difficult approach roads. In the case of the smaller reservoirs where the bulk of the use comes from the neighboring communities and farms, travel distance is a prime consideration. If the area is within an hour's drive, the day use may be expected to be of importance; if more than 2 hours' driving distance away, the area probably will not be used extensively unless overnight accommodations are available.

Population of region.—In general, the recreational use of a reservoir is in proportion to the population density of the region in which the reservoir is located, but a number of limiting factors enter into the picture, such as the character of the population, climate, nature of site, operation of the reservoir, type and quality of the facilities provided, administration, and maintenance.

It has been found that a larger percentage of the urban than the rural population may be expected to use the reservoirs for recreation; also that reservoirs located in the recognized vacation regions as, for example, the winter vacation region of southern Arizona and the summer vacation region of Colorado, will have a greater use due to the number of people in the region primarily seeking recreation.

NATURE OF SITE

The topography of the reservoir area determines to a considerable degree the amount of recreational use that can be made of the area. Reservoirs situated in open valleys usually offer more and better opportunities than those located in steep-sided canyons, where access to the water is difficult and sites for recreational facilities are limited. On the other hand, a very flat slope is also objectionable because of the wide shift of the water line between high and low water levels, frequently leaving unsightly mud flats exposed between the usable land above high water and the lake. The ideal situation is where the top of the dam is determined by a flattening of the topography so that there are gentle slopes adaptable to recreational development near both the high and low water lines.

Sandy soil along the shore line and the presence of trees and shrubs for shade and stabilization of the soil are other assets. Freedom from mosquitoes and other annoying insects is an important consideration in selecting sites for camping, swimming, and other activities.

Outstanding land forms, colored rock, interesting plant growth, or historic and scientific features in the vicinity of a reservoir tend to increase the attendance at the area. Especially are visitors from a distance attracted to the area by the publicity given these special features.

Although the recreational use of a reservoir will depend to a large extent upon the quality of fishing that can be maintained, the adaptability of the reservoir area to a diversity of recreational activities will increase its use and value. As with fishing, however, the quality and adequacy of the recreational facilities will have much to do with the amount of use a reservoir area will receive.

Among the requisites for a successful swimming area are: A comfortable surface underfoot, sandy and free from mud, rocks, and weeds, both above and below the shore line; water temperature about 70°F. or above; protected shallow areas for small children and nonswimmers; and deep-water diving areas. Camping areas are more popular when some privacy is offered between camp sites, which means the presence of adequate plant growth for screening. Parking spaces convenient to the boat docks, beach, and picnic areas contribute to the success of the development.

PLAN OF OPERATION OF THE DAM

The value of a reservoir for recreation and wildlife depends almost entirely upon the plan of operation of the dam and the resulting effect on water levels in the reservoir. Power plants are usually better adapted to recreational use and wildlife than irrigation or flood-control reservoirs because a more constant water level is required for operation of the generators at maximum efficiency. Irrigation and flood-control reservoirs may be drained completely during the summer when the recreation season is at its height. As a general rule, however, only some of the smaller irrigation reservoirs are apt to be drained dry each year. In most cases the reservoirs are planned with a conservation or dead-storage pool and usually there is some hold-over storage in irrigation reservoirs.

In all reservoirs there will be some fluctuation of water level. Generally, the recreational and wildlife value will be in inverse proportion to the amount of fluctuation in water elevations and areas between maximum, average, and minimum pools and the rate at which the water level is raised and lowered. However, the effects of fluctuations are dependent upon a number of highly variable factors which seldom occur in identical combinations at any two reservoir sites. For this reason, the recreational and wildlife values must be estimated separately for each potential reservoir.

Effect of fluctuation in water levels on plants.—Degree and season of water-level fluctuation in reservoirs are fundamental to all other considerations because in the water, as on the land, plant life is the key link in the production of all other forms of life. Aquatic plants, like those on land, require the action of sunlight for the chemical process that builds up food substances in their green tissues. However, sunlight in sufficient strength to permit plant growth seldom can penetrate the water of even the clearest lakes to depths of much more than 50 feet and in some lakes the illumination is reduced by dissolved and suspended material to 1 percent of its surface intensity at a depth of only 10 feet.[6] For this reason, aquatic plant life is confined, essentially, to the shallow, more or less marginal areas of a lake or reservoir, which are precisely the areas most drastically affected by fluctuations in water level. In the majority of deep lakes, most aquatic animals also are confined to the surface layers because of the general decrease in oxygen as depths of 100 feet are approached. The relative productivity of a lake is proportional to its area rather than to its volume.

Obviously, a sudden drop in the water level of a reservoir can completely destroy the food-producing fringe of aquatic vegetation by leaving it high and dry. A sudden rise can be almost equally destructive by burying the vegetation in the cold, sunless depths. On the other hand, if the drawdown or inundation is slow enough to permit the gradual establishment of a zone of new plants below the shifting water level, the biological disturbance is considerably less severe.

In a body of clear water located in a region of high light intensity, the productive zone of vegetation can extend downward to a considerable depth, with the result that even abrupt fluctuations of water level amounting to several feet can be sustained without the loss of the major food-producing zone.

Relative transparency of the water, proportion of sunny days to overcast, temperature of the water in relation to plant growth—these and other variables must be evaluated before one can predict the exact effect either of *rate* or *amount* of water fluctuation on the aquatic life of a reservoir. In general, however, *gradual* fluctuations of up to 75 feet do not severely curtail the basic productivity of reservoirs in warm regions having a high light intensity. Lake Mead is a good example of this combination of factors. On the other hand, a similar fluctuation in a cold, mountaintop reservoir having a growing season of only 3 or 4 months probably would result in a biological desert.

Even where the extent and rate of water fluctuations do not prevent the establishment of aquatic plants in a reservoir, they have a vital effect on the *kinds* of plants that can survive there. Plants that multiply and spread very rapidly obviously can advance and retreat with moving water levels by a process of individual replacement better than those that grow and propagate slowly. Microscopic plant forms, like green algae, that coat lake bottoms, submerged rocks, and dock pilings with a green slime or "moss," are able to replace them-

[6] Clarke, 1939, p. 29.

selves in a few days, and thereby can shift with the waters far more readily than large slow-growing perennial plants of higher evolutionary types like the cattails, pondweeds, and ditch grasses.

> In general, a drawdown of over 18 inches or two feet would have a deleterious effect on many food plants for ducks, even though cattails, giant bullrush and some others of little or no value would still do all right. On the other hand, a rather slow drawdown of ten or twelve feet, provided it did not have too much effect on the area of the reservoir . . . might be good for fish by minimizing weed growth.[7]

Weed growth is deleterious to fish in that the fish-food organisms, to which such growth gives shelter, becomes inaccessible to the fish. As a result, production of fish is less in a pond with weedy vegetation. The effects of fluctuation in a given reservoir obviously are dependent upon many variables. For example, "a short period (two to six weeks) of flooding is usually good for ducks because it promotes growth of lake-margin food plants without injuring those adjusted to normal level. That is if the flooding occurs before the nesting season, or if after the nesting season only lasts a week or ten days. In the case of draw-down, both the rate and the time of year would be important."[8]

Effect on animals. — There will be no large aquatic plants along the margins of reservoirs having water-level fluctuations of more than 10 feet during the growing season. Since these plants comprise the principal food supply and habitat of waterfowl, the absence of these plants seriously curtails the wildlife and recreational values of reservoirs. The role of such relatively barren bodies of water in the conservation of waterfowl will be relatively minor because nesting opportunities will be few. Therefore, such areas will be of little use except as temporary stopping places along the routes of migration. Unfortunately for recreation and wildlife conservation, most of the existing reservoirs in the Colorado River Basin are of the excessively fluctuating type. Stable reservoirs with ample food and cover are all the more critically needed in this region because of the prevailing scarcity of suitable natural areas for waterfowl. Reservoirs that control floods also eliminate many of the ponds and marshes that normally are formed along river bottoms during periods of overflow. Thus, former breeding grounds of waterfowl, muskrats, and other marsh-dwellers are destroyed, and the need of additional stable reservoirs with food and cover becomes all the greater.

Lack of an extensive growth of large aquatic plants does not in itself mean that a reservoir fluctuates so much as to be unsuitable for fish. If the fluctuations are not too violent, and if other growing conditions are favorable, microscopic and filamentous algae may be produced in such enormous quantities that they blanket all the shallow, sunlit depths. This microscopic aquatic forest teems with such "game" as the larvae of midges, mayflies, stoneflies, caddisflies, dragonflies, tiny crustacea, aquatic beetles, snails, worms, rotifers and other fish foods.

> Fluctuation, especially if it is at all rapid, may have an extremely deleterious effect on the bottom fauna, such as the *Tubifex* worms, and larvae of *Chironomus* and other midges. These are of very great importance as fish food . . . The bugs that burrow in the surface of the mud (and these are probably of greatest importance to the fish) have very little motility . . . The fish are concentrated, since most of them stay in the reservoir, while the bottom fauna dies off in considerable part, and the plankton, which has little control over its general movements, drains out with the water or else readjusts its total mass to the new size of the lake within a few days. This leaves the fish in a pretty pickle.[9]

The other major source of food in lakes and reservoirs is furnished by the billions of microscopic free-floating and swimming plants and animals known as plankton. Though usually invisible to the casual observer, the plant forms sometimes become so abundant under proper conditions of temperature, light, and fertility as to impart a greenish tinge to the water. Smaller animal plankton like the one-celled protozoas, as well as the plant forms of plankton, are eaten by larger plankton forms such as rotifers, or the barely visible crustacea known as "water fleas." These in turn are eaten by the aquatic insect larvae and by small fish (which

[7] Bond, 1945, letter.

[8] Bond, *lit. cit.*

[9] Bond, 1945, letter.

also consume some of the small plankton directly), and these insect larvae and small fish, plus some plankton, comprise the principal food source for the larger fish. The basic productivity of reservoirs with bare shore lines is dependent partly upon the submerged and largely unseen shallow-water blanket of algae and, even more importantly, upon the invisible plankton swarms.

Terrestrial insects that fall into the water furnish a supplementary source of food for fish during the summer months, but the amount of such food is correlated with the amount of land vegetation near the shore. In the Colorado River Basin most of the reservoirs have bare shore lines of varying extent so that this source of food is relatively unimportant.

Water fluctuations are additionally harmful when they crowd fish into small residual pools where they suffer from oxygen depletion, lack of food and predation.

> Strawberry Reservoir, in Utah, . . . was built on a tributary of the Duchesne River to store water for irrigation and happened to cover a very productive meadowlike area. The production of trout in that area was phenomenal, but the oxygen demands of the abundant organic material in the basin was sufficient to suffocate the trout while under the ice of midwinter. The drawdown during the irrigation season was so great that the trout were forced to live in the oxygenless zone near the lake bottom.[10]

Spawning beds, and shallows used by fish as refuges from attacks by larger fish, may be drowned out or left dry by such fluctuations. A benefit to wildlife and recreation may result from certain reservoirs if, in addition to reducing destructive floods, the release of water below the dam is so controlled as to augment a normally meager stream flow by providing additional water in late summer and fall.

WATER TEMPERATURES

Reservoir temperatures are a product of the complex interplay of temperatures of incoming streams and of local seasonal climatic conditions. Factors such as the relation of total volume of water to surface area exposed to the air, relative depth of water, interplay of sub-surface currents, volume of incoming water, mixing and oxygenating effects of winds, and the degree and duration of seasonal climatic changes are all variables contributing to the changing subsurface "climate" of reservoirs. Complex stratification of temperature zones in the deeper lakes results from the interplay of these and other factors, and these temperature stratifications are altered more or less radically by the changing of the seasons. Naturally, this emphasizes again the need of making an individual planning study for each reservoir and the difficulty of making general statements as to the effects of reservoir construction.

As previously pointed out, natural lakes and reservoirs in the higher mountains of the Colorado River Basin warm up for only a few weeks during the short summer season. Productivity is low because plant growth ceases at temperatures of around 40°F., the exact temperature varying with the species of plant. Many small organisms go into hibernation for the winter. Trout (and other fish) feed but little at temperatures near 32°F., and become more or less dormant.

Other favorable factors sometimes compensate for the short growing season of the higher altitudes. Abundant light and clear waters may favor the rapid growth of a zone of bottom-dwelling algae or aquatic mosses to a considerable depth, and the development of a large plankton population, as at Crater Lake, Oregon, where fish growth is excellent despite a water surface elevation of 6,177 feet, and summer surface temperatures of between 47° and 63.6°F.[11] Obviously, it is more important that fluctuations in water level be kept at a minimum in reservoirs at the higher altitudes because plant growth, being slower, cannot adapt itself to changing levels as rapidly as at lower altitudes.

At the lower altitudes, the higher temperatures afford a potential growing season that sometimes extends throughout the year, and in desert regions particularly there may be abundant light. However, in the Colorado River Basin, a prevalent adverse factor that more than offsets favorable light and temperaure conditions is the presence of large quantities of silt, which cuts out the light, smothers bottom-dwelling food plants and spawning

[10] Moffett, James W., letter, 1/15/46.

[11] Hasler, 1938, p. 94.

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grounds, and suffocates fish. If the reservoir is large enough to provide clear water beyond the area of silt deposition, production of plant and animal life may be extremely vigorous, provided water-level fluctuations are not extreme.

The most favorable growing temperatures for trout under natural conditions appear to be between 50° and 70°F.,[12] with 70°F. close to the upper safe limit, and 80°F. too high if sustained for any length of time.[13] Trout require water of a higher oxygen content, but can endure lower winter temperatures than the warm-water fish, such as bass. The latter require warmer waters for feeding and spawning.[14] The general life zone requirements of the two types of fish already have been discussed in Chapter I.

FERTILITY OF THE RESERVOIR

Aquatic plants, like those on dry land, require fertile soil containing organic matter, as well as warmth, for maximum productivity. For this reason, many reservoirs in the Colorado River Basin will be unable to compare in lush productivity with reservoirs in other parts of the country that have a richer soil.[15] The silt, resulting from both natural and man-caused erosion, that collects in so many of the lower reservoirs of the basin, is composed largely of inert subsoil and lacks the required organic matter. Reservoirs in the higher mountains, though more fertile, are handicapped in their productivity by prevailing low temperatures. Thus, in fertility as in other characteristics, it will be seen that few reservoirs in the basin will combine all of the elements necessary for maximum productivity.

Aquatic biologists have almost universally noted that new reservoirs exhibit a relatively high rate of productivity during the first few years following construction, but that this initial productivity eventually drops to a lower and more permanent level. Lake Mead is a good example.

> This above-normal production, I believe, can be attributed to the accumulation of organic materials on the floor of the reservoir site which are suddenly brought into the aquatic complex by the new waters as they flood them for the first time. I have noticed this phenomenon in several reservoirs of the Colorado River drainage in Utah and also in waters of California . . . I am (also) of the impression that as soon as the first 'bloom' of production in most high mountain reservoirs is over, the resulting production is not much greater than what might have been expected from the stream before the reservoir was constructed. This assumption is likely to hold in steep-sided, mountainous reservoirs with a minimum of shoal water. Naturally this comparison cannot be made in all instances.[16]

[12] Needham, 1938, p. 313.
[13] Wales, 1939, p. 303.
[14] Dill, 1944, p. 130.
[15] Moffett, 1942, p. 80.
[16] Moffett, James W., *lit. cit.*

CHAPTER VI

Potential Reservoirs

The survey of the recreational resources of the Colorado River Basin involved the consideration and investigation of about 135 potential reservoir sites. (Plate 15 in pocket.) The object of the investigation was to ascertain, at least in a preliminary way, the character of the area which would be flooded or affected by the reservoir; the recreational and scientific importance of the scenic, historic, geologic, archeologic, or biologic features of the reservoir area; the effect the potential project would have on important existing features; and the potential recreational values of the reservoir area.

In most instances, project plans had not been completed for the dams and reservoirs, and in many cases the only information available at the time was the approximate location and purpose of the dam and the size of the reservoir. Hence, it was not possible to make a final appraisal of the potential recreational values of the reservoir. Generally, however, it was possible to determine whether important recreational features existed in the reservoir area and whether the potential reservoir would or could have recreational values.

In a number of cases, particularly in regard to smaller reservoirs, the recreational potentialities of the site will be increased considerably if, as the project investigations progress, it is found possible to provide a dead storage or conservation pool.

For convenience in planning the development of the water resources of the Colorado River Basin, the Bureau of Reclamation has divided the basin into seven main divisions suggested by physical characteristics. The same divisions are used in the following discussion.

GREEN RIVER DIVISION

Upper Green River Basin.—In the Upper Green River Basin, the Flaming Gorge, Red Canyon, Fontenelle, and Kendall Reservoir sites appear to be of most importance for recreation. The mile-long Flaming Gorge of the Green River is unusually colorful but it is not unique or outstanding in comparison with the colorful scenery found farther down the Green River. However, the combined scenic and geologic interest of Flaming Gorge, the nearby Horseshoe Canyon, and the canyons of Sheep Creek, plus the proposed reservoir would make this section of considerable recreational value. There is certain to be a demand for recreational facilities in the vicinity of the dam and at one or two points up the reservoir to serve people traveling through the region and those living in the vicinity of Green River, Wyo.

The Red Canyon Dam site, 31 miles below Flaming Gorge, is also in the scenic country on the north side of the Uinta Mountains. With the Flaming Gorge Dam the Red Canyon Reservoir should be fairly free of silt and should offer good fishing possibilities. The sheer walls of the canyon, however, greatly limit the possible use of the reservoir for recreational purposes.

The Fontenelle and Kendall Reservoirs on the Green River in Wyoming would be primarily of local recreational interest, but would receive some tourist use because of the proximity of United States Highways 189 and 187.

Most of the other potential reservoirs lie in the open sagebrush plains and hills and would offer little in the way of recreational attractiveness because of summer drawdown and lack of cover. Burnt Lake, lying within the Bridger National Forest, is notable for its natural scenery and its nearly complete freedom from artificial development. Alteration of the water level, as has been proposed, would ruin the scenic and recreational values of the lake.

Yampa and White River Basins.—The Juniper and Upper Bear Reservoir sites are conveniently

Figure 51.—Flaming Gorge—looking down Green River to dam site. This is where the Green River starts cutting through the Uinta upwarp.

Figure 52.—Fontanelle Reservoir site—looking upstream from dam site.

Figure 53.—Burnt Lake on the west slope of the Wind River Range.

Figure 54.—Hades Reservoir site—looking up the Duchesne River Valley.

located to serve the more populated sections of the basin. With some development of recreational facilities and fishing, they should be popular with the local people and those traveling through the region. The other reservoir sites are situated in sparsely populated areas and would have little effect on the recreational resources of the basin.

Uinta Basin.—The two potential dam and reservoir projects, Echo Park and Split Mountain, will effect Dinosaur National Monument. These projects are discussed in Chapter IX.

The many good lakes and streams in the Uinta Mountains lessen the need for water recreational areas in the adjoining Duchesne and Ashley Valleys. However, the proposed Pelican Lake, Starvation, Stanaker and Red Creek Reservoirs should have some local recreational value. Crow Creek, in a remote location, would probably receive little use. The Hades site is on one of the main approach roads to the High Uintas Primitive Area. The proposed reservoir development would not compensate for the loss of the present recreational assets. The enlargement of Strawberry Reservoir is not likely to increase its present recreational values unless the percentage of drawdown on the enlarged reservoir is less than that of the present one.

Price and San Rafael River Basins.—This section lacks natural water areas suitable for recreational use. Hence, all of the sites, except perhaps the Buckhorn which is in desert country and would be subject to complete drawdown, should be planned for recreational use by the residents of the nearby irrigated districts. The Mammoth and Joes Valley sites in the Manti National Forest at fairly high elevations appear to offer the best possibilities.

The two large potentialities in this subdivision are the Desolation and Rattlesnake Dams located in the remote and almost inaccessible canyons of the Green River. The reservoirs formed by the two dams would extend from a few miles north of Green River, Utah, almost to Ouray, Utah. The main access of the reservoirs would be from these two towns. Although the reservoir areas have only been investigated from the air, it is doubtful that the scenic or recreational values, either existing or potential, will be found important. Present information indicates that scenically this section does not compare with sections along the Green above Jensen, Utah, and below Green River, Utah. Some archeological sites of importance have been found in side canyons, indicating that an archeological survey of the reservoir areas should be made well in advance of the completion of these projects.

GRAND DIVISION

Of all portions of the Colorado River Basin, the Grand and San Juan divisions have the best natural water areas and the least need for artificial lakes. However, with the great number of tourists attracted to the region, additional water bodies that do not interfere with or eliminate existing recreational resources should be of considerable benefit. The McPhee and Dewey Reservoir sites are well located to provide new recreation areas. A number of other sites might provide opportunities for local use such as Castle Creek, Gurley, Rabbit Ears, East Troublesome, Barbers Basin, Fourmile No. 4, Rifle Gap, Tomichi, McDonough, Grand View, Finch, Cottonwood, Miramonte, Buckeye, Mill Creek, Coyote, East Canyon, Owens Creek, Vega, Castle, and Gorsuch. The last four sites, however, will have to compete with the lakes and reservoirs on top of Grand Mesa for attendance and use.

The Dewey Reservoir site is on the Colorado River, in eastern Utah and western Colorado and about midway between the north and south boundaries of the two States. By far the greater part of the reservoir site, which is more than 40 miles in length, lies in Utah. Only a small portion of it extends into Colorado. The tentative dam site is about 30 miles upstream from Moab, Utah, at the upstream end of the spectacular Red Canyon of the Colorado River that lies between the dam site and United States Highway 160 near Moab.

The purpose of the proposed project is the development of hydroelectric power. Preliminary studies by the Bureau of Reclamation indicate a water surface of about 66,000 acres at full reservoir and about 21,000 acres at dead storage. Maximum drawdown, which normally would occur during the winter months, would be about 106 feet.

Lands involved include State school lands, privately owned lands, and public domain. The greater part of the area is semi-desert grazing land having little scenic or recreational value. However,

in the vicinity of the Dewey Bridge there are distinctive sandstone cliffs and box canyons, and the canyon of the Dolores River which enters the Colorado River about a mile and half above the dam site is colorful and interesting. The Westwater Canyon of the Colorado River, the principal scenic feature of the reservoir area, is about 12 miles long and several hundred feet deep. Deep tributary canyons enter on its easterly side, and both the main and tributary canyons are characterized by sandstones that have a pleasant reddish hue. Views from the west rim are good, particularly in the Big Hole section, and from the air the Westwater Canyon and the numerous and intricate side canyons on the east form a notable scene. When compared, however, with some other areas on or near the Colorado River in the same general region of eastern Utah and western Colorado, such as the Colorado and Arches National Monuments, the canyon of the Colorado River between Dewey Bridge and Moab, and the amazing landscapes near the junction of the Green and Colorado Rivers, the Westwater Canyon is clearly of secondary scenic importance.

The proposed reservoir would be a large lake of very irregular shoreline, and because most of the area it would cover slopes somewhat gently toward the Colorado River, drawdowns would expose considerable amounts of unsightly bottom. In the locality of the Dewey Bridge, where at full reservoir the water would be approximately 290 feet deep, a good deal of the colorful sandstone would be submerged. In the vicinity of the Big Hole portion of Westwater Canyon, the reservoir at high-water level would be about 200 feet deep, materially altering the appearance of the canyon by reducing its apparent depth and substituting a still body of water for the rapidly flowing river. Nevertheless, the canyon would retain some of its scenic value, and recreational resources would be added, because the lake would offer opportunities for boat trips, fishing, swimming, and camping.

While the Dewey Reservoir would not be of special recreational importance to the immediate vicinity since the local population is very sparse, the lower portion would be of some recreational usefulness to residents of Moab, and the Westwater Canyon would be of interest to travelers using

Figure 55.—Castle Creek Reservoir site north of Gunnison, Colo.

United States Highway 50 and to residents of the Grand Junction area, provided it were made reasonably accessible.

It has been indicated by the Bureau of Reclamation that a road for construction purposes would have to be built from United States Highway 50 and the Denver and Rio Grande Western Railroad to the dam site. It is recommended that this be built as a permanent road, to connect with the unsubmerged portion of Utah State Highway 128 between the dam site and United States Highway 160 near Moab. This would, in effect, retain the present route from Moab through the spectacular Red Canyon of the Colorado River to United States Highway 50, which not only is used as a short cut from Moab to Grand Junction, but affords access to the remarkable spires and buttes of this part of the Colorado River Canyon.

Consideration should also be given to providing access by automobile from United States Highway 50 to a limited recreational development at the Big Hole. Provision for boat trips in the canyon would be desirable. Public control of the reservoir shores and of the Big Hole would also be desirable.

The area to be inundated is reported to contain several archeological sites and exposures of fossilized dinosaur bones. Fragments of petrified wood are abundant. While it seems doubtful that any unmolested archeological sites remain to be discovered, it is recommended that an archeologist investigate the area well in advance of reservoir construction in order to record any important sites that would be inundated. It is also recommended that the paleontology of the area be similarly investigated.

The McPhee Reservoir site is in the beautiful Dolores River Valley, a short distance down stream from the town of Dolores, Colo. The natural conditions are ideal for creating an artificial lake of considerable beauty and recreational value. Fishing is good in the upper sections of the Dolores River and should be good in the reservoir. This section of the Dolores Valley is now used for pic-

Figure 56.—Lake San Cristobal near Lake City, Colo.

Figure 57.—Dewey Reservoir area—typical terrain of east side north of Dolores River.

Figure 58.—Westwater Canyon of Colorado River at Big Hole—Dewey Reservoir area.

Figure 59.—Canyon of Colorado River near Colorado-Utah State line. *(Air photo)*

Figure 60.—McPhee Dam site—looking down Dolores River Valley.

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Figure 61.—McPhee Reservoir site—all the lowland in picture would be flooded.

nicking, camping, and fishing, and with the reservoir these uses should increase. There were 12,421 people living within easy access of the site in 1940. It is recommended that plans for development of the area include acquisition of all the shoreland and the provision of recreational facilities for public enjoyment of the reservoir including boat docks, swimming beach, picnic areas, camping areas, and the relocation of the present road through the proposed reservoir area to maintain the scenic drive down the Dolores Valley.

Other reservoir sites.—Among the sites in the Grand Division that are probably more valuable for recreation as they exist than if dams were constructed are the attractive Eggleston Lake, Lake Brennan, and Lake San Cristobal, and the scenic locations in which Beaver and Banana Ranch Reservoir sites are situated. Missouri Heights Reservoir, as it exists, offers some possibilities for recreation that would not be increased if it were enlarged. The Sapinero Dam would flood a 20-mile section of the extremely popular Gunnison River fishing area and substitute a still-water area which probably would not compensate for the loss of the stream. A dam at the Moab site, just above the Moab Highway Bridge, would eliminate the only scenic drive through one of the impressive canyons of the Colorado River in Utah. The present character of the canyon is undoubtedly more of a recreational asset than reservoirs would be in this location. Several other sites in the Grand Division may not create new values or interfere with existing values. In general, the transmountain diversion projects in Colorado probably will be to the detriment of the recreational values of the region in which they are located. The necessary canals in most cases will cut into attractive mountainsides, and water diverted from the natural channels will decrease the amount available for fishing and other uses downstream.

Special studies should be made of the recreational possibilities of areas like Whitewater during the planning stages to insure the maximum benefits.

SAN JUAN DIVISION

This division includes the San Juan River drainage and the western tributaries of the Colorado River between the junction of the Green and Colorado Rivers and Lees Ferry. The major dam and reservoir proposals in this division, Glen Canyon and Dark Canyon Dams in the Colorado River and the Goosenecks, Slickhorn, and Great Bend on the San Juan, are discussed in Chapter VIII.

The Bluff Dam in the San Juan River, 12 miles below Bluff, Utah, would create a reservoir with a maximum surface area of 28,500 acres and a minimum area of 7,800 acres. Since the reservoir would be located in a region of very sparse population and is to serve primarily for silt retention and flood control, it is not likely to have much value for recreation. The natural scenic attractions in southeastern Utah and northeastern Arizona will, no doubt, appeal more to the tourists than will this reservoir.

Of the other 24 potential sites in this division the O'Neal Park, Howardsville, Hermosa Park, and Mill Meadow sites seem to offer the best possibilities for recreational development and use. They can be definite assets to the recreational resources of the division. O'Neal Park site is in an open, high, mountain valley easily accessible from Pagosa Springs, Colo., and United States Highway 160.

The Howardsville site is a short distance up a deep valley from Silverton, Colo., at an elevation of 9,700 feet above sea level. The reservoir could be developed in conjunction with the old mining town of Silverton into an impressive high mountain resort area.

Hermosa Park is an attractive basin about 5 miles long and one-half mile wide, bounded on the west and north by mountains which rise to more than 12,000 feet above sea level. A lake occupying part of the basin would add to the numerous existing recreational assets of the region if the preliminary plans for the project providing for a complete drawdown can be changed to include a substantial dead storage pool.

A reservoir at the Mill Meadows site on the Fremont River below Fish Lake could add materially to the recreational assets of that popular summer vacation region.

The proposed Silverton, State Line, Meadows, Monument Rocks, Recapture, Torrey, and Escalante Reservoirs would probably be of local value only. Two natural, high mountain lakes having existing values that would be impaired by enlarge-

Figure 62.—Hermosa Park Reservoir site north of Durango, Colo.

Figure 63.—Lemon Reservoir site northeast of Durango, Colo.—Florida River flows along the far side of meadow.

Figure 64.—Virgin City Dam site—most of the land in the middle distance would be flooded. Towers of Zion National Park form background.

Figure 65.—Horseshoe Reservoir site in Verde Valley, Ariz.

ment are Emerald Lake and Divide Lake. Other reservoir developments that would probably be detrimental to existing recreational values would be at the Navajo, Blanco, West Fork, Lemon, and Teft sites. Aside from the consideration of archeological values, reservoir construction at the other sites would not affect the recreational picture.

The San Juan Division is rich in archeology and surveys of the reservoir area should be made well in advance of construction of the dams.

LITTLE COLORADO DIVISION

Of the five potential reservoirs in this division, the Forks site located near Holbrook, Ariz., and Petrified Forest National Monument offers the best possibilities for recreational development and use. Preliminary plans call for a reservoir having an average water surface of 4,300 acres with a maximum fluctuation in water level of only 10 feet. The reservoir area should include a protective strip of land around the entire lake and a suitable area for public recreational use.

Though the other reservoir projects are not likely to be of recreational importance. they are located in a region rich in archeological remains. Archeological surveys should be made of the reservoir areas well in advance of construction operations.

VIRGIN DIVISION

The Virgin City Reservoir site on the Virgin River near Zion National Park is suitable for the development of an important water recreation area that will supplement the scenic attractions of the park. Many of the visitors to Zion National Park and the people living in the valley would use the reservoir for picnicking, camping, swimming, fishing and boating. The proposed Lower Gunlock Reservoir on the Santa Clara River in Utah and the Delmue Reservoir near Pioche and Caliente, Nev., should be attractive to the people living in the vicinity.

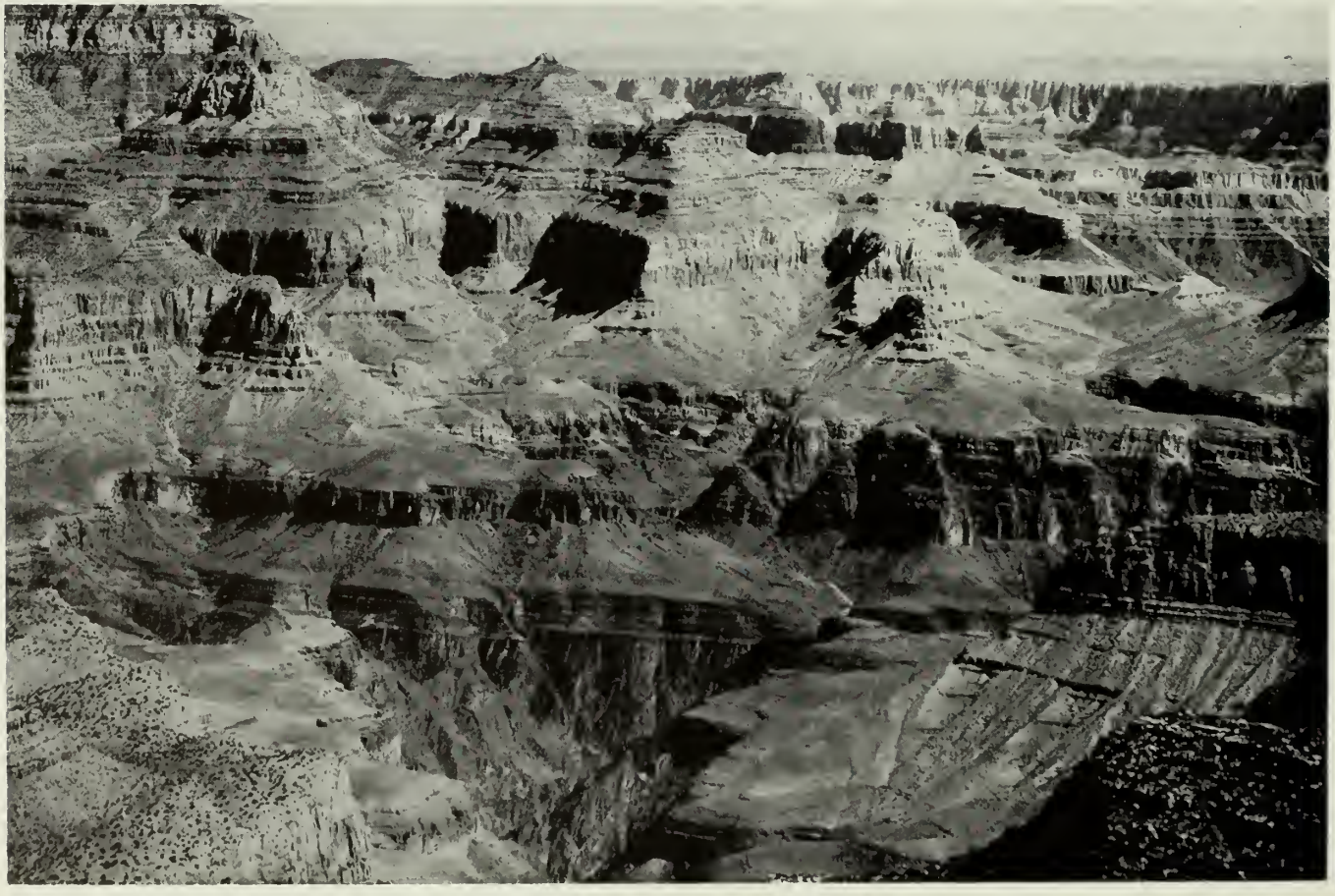

Figure 66.—The Grand Canyon from Grandview Point.

BOULDER DIVISION

The two major proposals in this division, Marble Gorge and Bridge Canyon Dams, are discussed in Chapter VII. The site for the proposed Coconino Dam is in the canyon of the Little Colorado River 8 miles below Cameron, Ariz. Cameron, an Indian trading post and tourist court, is on United States Highway 89, near the junction of that highway and the east entrance to Grand Canyon National Park. The proposed dam, rising 260 feet above bedrock, would create a reservoir having a maximum surface area of 36,000 acres and a minimum surface area of 1,000 acres, with a 40-foot difference in water levels between the two.

Considering that there will be a wide variation in water surface area, that the primary purposes of the reservoir are silt and flood control, and that there is not likely to be good fishing, the reservoir will have little recreational use.

The other two potential reservoirs in this division are the Alamo on the Bill Williams River and the Sentinel on the Gila River. Both reservoirs are proposed for flood and silt control. Due to the sparse population of the region and the uncertain flow of the rivers, these reservoirs probably will have little or no recreational value.

GILA DIVISION

All of the proposed reservoirs in the Gila Division will have some recreational use because of the absence of natural lakes in this important recreational region. Each reservoir should be planned and developed to provide for as much recreational use as is possible consistent with the primary use of the water. The McDowell and Horseshoe sites are suitable for the development of important recreational areas serving the Phoenix metropolitan district. The Buttes Reservoir would serve the Florence area; Box Canyon, the Wickenburg area; and Charleston, the Tucson-Bisbee area.

The Grand Canyon

From the mouth of the Nankoweap Canyon on the east to the Grand Wash Cliffs on the west—more than 200 miles by river—the Grand Canyon maintains approximately the same 5,000-foot depth and a width between rims measured in terms of miles. All sections of the Grand Canyon are parts of one natural physiographic unit. Although the general character and form of the canyon change greatly from place to place, there is an imperceptible transition from one section to the next, and all are inseparable parts of the one great canyon.

Man-made boundaries in the Grand Canyon mean nothing as to the relative value of different portions. It is not possible to say that one part is either inferior or superior to another; each is different but each is great and part of the whole.

BRIDGE CANYON RESERVOIR SECTION

The inner part of the Grand Canyon which would be affected by the proposed Bridge Canyon Reservoir may be divided both scenically and geologically into four main divisions. The eastern division of the inner canyon, starting some miles above the mouth of Havasu Creek and extending almost to Toroweap Valley, is characterized by extreme narrowness of the gorge and by very high sheer walls of sedimentary rocks. Near the mouth of Havasu Creek, for instance, resistant beds of Muav limestone wall in the river and the soft shales that normally form the flat Tonto Platform below are not exposed, with the result that the inner canyon to a height of nearly 2,000 feet is extremely narrow, probably the narrowest within the entire canyon.

From Toroweap Valley to Whitmore Wash and beyond, the scenery has been changed by the introduction of vast quantities of volcanic materials and the cutting of the river progressively deeper into the sedimentary rocks, with consequent widening of the gorge. The Toroweap section is one of the most spectacular and remarkable parts of the Grand Canyon. At the foot of Toroweap Valley the nearly vertical walls of the inner gorge rise almost 3,000 feet above the river. Great lava flows have cascaded down into the gorge and cinder cones perch on slopes within the canyon. On the rim of the gorge at the foot of Toroweap Valley stands a large cinder cone known as Vulcans Throne.

Below Whitmore Wash the river turns south following the trend of several major fault lines—especially the Hurricane Fault to the north and the Peach Springs Fault to the south. The entire aspect of the canyon changes. It is considerably wider and cut into older rocks than those exposed in the Toroweap area. The most impressive part of this section is known as Granite Park.

From the great bend of the Colorado River at the mouth of Diamond Creek westward to and beyond the Bridge Canyon Dam site, the Colorado flows through the lower Granite Gorge, and the scenery near the river resembles that in the inner gorge of the Bright Angel section. Above the inner gorge the Tonto Platform also shows a resemblance to the corresponding feature in the eastern section of Grand Canyon.

On the south side of the canyon the great Cataract Plain extends west from the Williams-Grand Canyon Road to the Aubrey Cliffs—unbroken except for Cataract Canyon. West of the Aubrey Cliffs to the Grand Wash Cliffs are vast colorful canyons, plateaus, and mountains.

Prospect Canyon, which parallels the Aubrey Cliffs, provides a means of access to the high east rim of the canyon overlooking Granite Park. In this section, from Granite Park to Diamond Creek, the Grand Canyon reaches its greatest depth. The rim attains an elevation of 6,890 feet while the river at the mouth of Diamond Creek is at an elevation of 1,335 feet. From the piñon- and juniper-covered

rim there are magnificent views of the brilliant canyon and the surrounding country. Hualpai Peak 72 miles to the southwest, the Music Mountains, and Peach Spring Wash are visible. To the northwest is the Shivwits Plateau. Below is Granite Park. Across the river to the north are the Pine Mountains, Parashont Canyon, and Whitmore Wash, and rising out of the red Tonto Platform like a huge ant hill is a volcanic cinder cone. The lava flow down from Mount Emma ending abruptly in Whitmore Wash and the gigantic row of red Supai windows projecting through the lava are also plainly visible. The scene is entirely different from that of the Bright Angel section but equally grand. There

Figure 67.—Burnt Springs Canyon from Twin Point—Grand Wash Cliffs form the skyline.

are fewer dramatic formations in the canyon but a greater variety of land forms and an endless horizon.

Peach Spring Draw, which joins Diamond Creek just before it enters the Colorado, provides the only natural grade suitable for a road to the bottom of Grand Canyon. Before the railroad was built to Grand Canyon Village, the old Diamond Creek Hotel near the mouth of the creek was the most popular place in the Grand Canyon. It may become popular again as an access point to the reservoir if Bridge Canyon Dam is constructed. Diamond Peak, near the junction of Peach Spring Draw and Diamond Creek, is one of the well-known geologic features of the canyon.

Spencer and Meriwitica Canyons, west of the Bridge Canyon Dam site, are fine examples of side

Figure 68.—Looking toward Whitmore Wash and Pine Mountains from Shivwits Plateau.

Figure 69.—Bridge Canyon and Gneiss Canyon (right). The inner gorge of the Colorado River is about 800 feet deep. *(Air photo)*

canyons. Meriwitica Canyon is of special interest for, according to tradition, it is the original home of the Hualpai Indians. Between Spencer Canyon and the Grand Wash Cliffs the high points on the rim of the canyons offer views of canyon scenery as rugged, colorful, and interesting as any part of the Grand Canyon.

North of the river the region is divided into a series of canyons and plateaus. East of Kanab Canyon is the high, pine-covered Kaibab Plateau. Between Kanab Canyon and Toroweap Valley on the west is the comparatively uninteresting Kanab Plateau. However, from the rim of this plateau as at Boysag Point, Kanab Point, and Toroweap Point, there are marvelous views of the Grand Canyon. West of the gently sloping 3-mile-wide Toroweap Valley are the Pine Mountains, a series of forest-covered volcanic cones striped by large lava flows. West of the Pine Mountains are the spectacular Whitmore Wash and Parashont Canyons. Beyond them is the Shivwits Plateau, a green peninsula in the sky flanked by brilliantly colored deserts and canyons. The Toroweap-Whitmore Wash area, including the Pine Mountains and Parashont Canyon, is the most outstanding section west of Kanab Canyon. Here are the great faults, evidences of volcanic activity, pine forests and desert vegetation, springs, deep narrow canyons, and color.

The recreational value of the Shivwits Plateau is primarily in the fine views of the Grand Canyon from the rim and its remote wilderness character. However, the views are not unlike those obtained from the east rim of the Grand Canyon above Diamond Creek, and the high points along the latter rim are about 300 feet higher than Mount Dellenbaugh, the highest point on the Shivwits Plateau.

LANDS AND AGENCIES INVOLVED

All of the Grand Canyon is within areas now administered by the Federal Government through the Bureau of Indian Affairs, the National Park Service, the Fish and Wildlife Service, the Bureau of Reclamation, and the Bureau of Land Management, all of which are in the Department of the Interior, and the Forest Service of the Department of Agriculture.

The eastern side of the canyon between Lees Ferry and the Little Colorado River is part of the Western Navajo Indian Reservation. From Lees Ferry to Nankoweap Canyon, the west side of the canyon is partially in the Kaibab National Forest and partially public domain. Grand Canyon National Park includes all of the canyon from Nankoweap Canyon and the Little Colorado River to Tapeats Creek. From the west side of Tapeats Creek Canyon to the west rim of Kanab Canyon, the area north of the river is part of the Kaibab National Forest. On the south side, Grand Canyon National Park extends west to include Havasu Canyon. Grand Ganyon National Mounment lies between Grand Canyon National Park and Lake Mead Recreational Area, the greater portion being north of the river. Lake Mead Recreational Area adjoins the southern portion of the monument on the west. South of the river, the Hualpai Indian Reservation extends from National Canyon almost to the Grand Wash Cliffs. Lake Mead Recreational Area overlaps the Hualpai Indian Reservation to include most of the Grand Canyon south of the river which is within the reservation.

BUREAU OF RECLAMATION PROPOSALS

Bridge Canyon Dam and Reservoir.—Nineteen miles northwest of Peach Springs, Ariz., in the seldom-visited western half of the Grand Canyon, the Bridge Canyon Dam may some day rise to the towering height of 740 feet above bedrock if the present plans of the Bureau of Reclamation are carried through. Exceeding Hoover Dam in height, this dam would in turn be dwarfed by the canyon. Though the dam would raise the water 672 feet to a maximum elevation of 1,876 feet above sea level, the multicolored canyon walls would tower more than 4,000 feet above the fiord-like lake. The quiet water of the lake thus created would extend upstream 93 miles to within a tenth of a mile of the mouth of Kanab Creek. At normal water surface elevation 1,866 feet, it would extend to within four-tenths of a mile of Kanab Creek. The minimum surface elevation of the reservoir would be 1,645 feet.

Bridge Canyon Dam is proposed primarily for the generation of power. Coincidental with the construction of the Bridge Canyon Dam would be the construction of the Coconino Dam on the Little Colorado River 49 miles upstream from the

Colorado River and the Bluff Dam on the San Juan River 132 miles upstream from its mouth. Both of these dams would serve as flood control and silt detention structures. The Bluff Reservoir also would regulate the flow of the San Juan as required by downstream power plants. These two dams are essential to the life of the Bridge Canyon Reservoir.

Marble Gorge Dam and Kanab Tunnel.—Following the Bridge Canyon, Coconino, and Bluff Projects in the Bureau's schedule of development would be the Glen Canyon Dam located 4.5 miles upstream from Lees Ferry. This dam would be for power development and river regulation. This project is discussed in Chapter VIII—Canyon Lands of Southeastern Utah. In the 150 miles between the Glen Canyon Dam site and the estimated headwaters of the potential Bridge Canyon Reservoir at normal water surface elevation, the Colorado River falls approximately 1,260 feet. About 100 miles and 950 feet of the drop are within the boundaries of Grand Canyon National Park. To take advantage of this drop and yet avoid the construction of dams or other works in the park, the Bureau of Reclamation suggests a plan for diverting the Colorado River waters "not needed to maintain a steady stream for scenic purposes in the park" through a 44.8 mile tunnel from just above the east end of the park to a power plant on the Colorado River near the mouth of Kanab Creek. The capacity of the Kanab Tunnel would be 13,000 second feet. A 298-foot dam at the Marble Gorge site 15.5 miles upstream from Nankoweap Canyon would divert water to the tunnel. Water released from the dam for scenic purposes in the park would pass through a power plant.

The maximum and normal water surface elevation of the Marble Gorge Reservoir would be 3,125 feet, the elevation of the Colorado River at the Glen Canyon Dam site, and the minimum water surface would be 3,115 feet above sea level.

Proposed operation of reservoirs.—According to present studies of the Bureau of Reclamation for reservoir operation in connection with the Parker diversion route of the proposed Central Arizona Project, Bluff and Coconino Reservoirs would be for the purpose of silt control. Glen Canyon and Marble Gorge would be future developments for river regulation, silt control, and power. Generally, the Marble Gorge Reservoir would be maintained at maximum content. However, during a critical year of operation the active content of Marble Gorge Reservoir would be withdrawn prior to utilizing the active content of Bridge Canyon Reservoir. Such withdrawal would be made only after the active storage contents of Bluff and Glen Canyon Reservoirs had been exhausted. Release through the Marble Gorge Power Plant would be at a uniform rate of approximately 1,000 second feet. Operation of the Kanab Power Plant would be closely coordinated with the operation of the Glen Canyon Power Plant.

Normally, after full river regulation is provided by upstream storage, Bridge Canyon Reservoir would be operated at maximum content with release of water for power corresponding to releases from Glen Canyon.

With this method of operation, the water surface elevation of Bridge Canyon Reservoir would normally be between 1,866 and 1,876 feet. Only in an extremely dry period would it be drawn down to a minimum elevation of 1,645 feet. The Marble Gorge Reservoir would have a maximum fluctuation of 10 feet between elevations 3,125 and 3,115.

EFFECT OF PROPOSED PROJECTS ON THE GRAND CANYON

The projects proposed for the control and use of the Colorado River would completely change the natural conditions and character of the river through the Grand Canyon. In place of a thundering, heavily silt-laden river, it would be harnessed by dams into a series of quiet mill ponds, except through Grand Canyon National Park where it would be diverted under the plateau through which it has for millions of years been grinding its own way. The silt and debris would be dropped behind upstream dams. The river through the Grand Canyon without its grinding agents would no longer be the Colorado known to thousands of visitors who go to the bottom of the canyon each season. It would be a clear stream.

In place of great fluctuations in volume of flow between the spring months when the snow is melting on the Rockies, the Uintas, and the White Mountains and the winter months when the pla-

Figure 70.—The Grand Canyon above Bridge Canyon—the high rim of Grand Canyon north of Diamond Creek forms the skyline.

Figure 71.—Havasu Falls—one of the four falls of Havasu Creek.

teaus are dry and the mountains frozen, the flow would be regulated to meet the demands of the power plants. Between Marble Gorge Dam and Kanab Creek, roughly the area covered by Grand Canyon National Park, the flow would be regulated to a constant 1,000 second feet.

With the series of dams proposed, silt and debris now carried by the Colorado River and deposited in Lake Mead would be drastically reduced. Navigation in the canyon section of Lake Mead, practically impossible at the present time because of silt conditions, would be stabilized, making it possible to travel with ordinary types of boats from Pierce Ferry to just below the Bridge Canyon Dam.

Bridge Canyon Dam and Reservoir.—The impounding of water behind Bridge Canyon Dam to an elevation of 1,876 feet probably would conceal few geological features that are unique or of special importance as documents of geological history. Any impoundment more than a few feet higher than that elevation, however, would back water beyond the upper reaches of the inner canyon to which it would otherwise largely be confined, and create a conspicuous, insistent intrusion into the broader part of the canyon visible from the rim. There would result an artificial reservoir replacing the natural river in some of the most spectacular and characteristic views of the canyon obtainable. The greatest losses, insofar as geological features are concerned, would be in the area of volcanic activity at and westward from Toroweap Valley. Several features illustrating the early stages of canyon cutting and of local volcanism would be inundated. Also covered would be the remnants of lavas that flowed down the river channel and, in two places, the sediments formed in ancient lakes or reservoirs behind natural lava dams. A detailed report on many of these features was made by Edwin D. McKee and Edward J. Schenk to the Director, National Park Service, in December 1941. The report is entitled "Lava Dams in Grand Canyon." The following statement appears in the report: "The spectacle of lavas that have cascaded down the steep canyon walls, and [of] cinder cones perched on the sides and brink of the chasm usually makes a profound impression on the layman, while to the geologist the problems presented are intriguing."

Toroweap Valley slopes gently toward the canyon rim and ends with a sheer cliff almost 3,000 feet above the river. The views down into the canyon, combined with the roar of the rapids, are spectacular and awe-inspiring. The increased width of the strip of water in the bottom of the canyon through submergence of the talus slopes would decrease the apparent depth and impressiveness of the chasm.

Havasu Creek, an unfailing spring-fed stream of crystal clear water, is a distinctive feature of the canyon. The notable and beautiful, though seldom seen, mingling of the blue waters of Havasu Creek with the brown waters of the Colorado would be radically altered for the worse. But the more frequently visited waterfalls and other features that have made Havasu Canyon famous would not be affected by the Bridge Canyon Reservoir.

Between Havasu Canyon and Kanab Creek the high, upper rim of the Grand Canyon is characterized by narrow, long projecting points, with deep bays between, and an abrupt descent from its edge to an exceptionally wide "bench" nearly 2,000 feet lower. The general appearance of the bench is extraordinarily flat, although it is dissected by minor canyons and has a number of isolated small buttes rising from it. This wide bench appears to be nearly bare of vegetation, has a peculiar and distinctive rock texture and color, and extends to a sharply defined edge much closer to the river and more nearly parallel with its course than is the case with this formation in the canyon farther east. The inner gorge lying between the two rims of this bench is correspondingly deeper and more closely shut in, making the river invisible from the upper rim except at a few projecting points, of which the most remarkable is Boysag Point. This point is much closer to the river than any point of the upper rim in Grand Canyon National Park. Views into the inner canyon from places on the inner rim would doubtless be impressive but that rim is at present extraordinarily difficult of access. Only a minute fraction of all the vistiors to Grand Canyon National Park thus far have ever obtained a good view of the depths of the inner gorge between Tapeats Creek and Havasu Creek, and probably most of that relatively small number have seen it only from the mouth of Havasu Creek. These con-

ditions, however, could be changed by later park developments.

For its entire length the Bridge Canyon Reservoir would be confined in the lower inner gorge and extend only short distances up side canyons. The largest arm would extend up Diamond Creek and Peach Spring Draw about 2.5 miles. The narrowest arm would extend more than 2.5 miles up the sheer-walled Parashont Canyon. The entire reservoir would be in colorful canyons of overwhelming grandeur, and the north-south section of this fiord-like lake between Diamond Creek, Granite Park, and Parashont Canyon, would be extraordinarily scenic.

The Act of February 26, 1919 (40 Stat. 1175) creating Grand Canyon National Park provides in Section 7:

> That, whenever consistent with the primary purposes of said park, the Secretary of the Interior is authorized to permit the utilization of areas therein which may be necessary for the development and maintenance of a Government reclamation project. (U.S.C., title 16, sec. 227.)

Various heights for Bridge Canyon Dam have been considered, but the one presently planned would have a maximum water surface elevation of 1,876 feet. This would raise the water 666 feet above the stream bed at the dam and place the head of the reservoir less than a mile downstream from the mouth of Kanab Creek. It would raise the water surface about 85 feet at the mouth of Havasu Creek, backing the water approximately one-half mile up Havasu Canyon in Grand Canyon National Park.

Frederick Law Olmsted, noted landscape architect, made a study of the probable effects of the proposed Bridge Canyon Dam upon the national park and monument. In his report Mr. Olmsted said:

> This section of the Grand Canyon as a whole is notable for the distinctive character of its scenery, especially as seen from certain places on the upper rim on both sides of the canyon. It was completely included from rim to rim in the portion of the Grand Canyon originally set apart in 1908 as a national monument for preservation of the noneconomic values of its unique and inspiring scenery. It was, and is worthy of selection for such a purpose.

When the Grand Canyon National Park was established in 1919, its boundaries were so drawn as to leave the entire north side of the canyon between Tapeats Creek and Havasu Creek under the administration of the Forest Service, which had previously administered all parts of the Grand Canyon set apart for preservation of its natural scenery in 1908. The investigators have found no record indicating that the omission of that area from the park was due to a deliberate and reasoned decision to reverse the earlier intention of protecting the scenery of this entire unit of the canyon from rim to rim.

If that is to remain the policy of the Government concerning this entire unit of the Grand Canyon, in accordance with the decision made in 1908 and adhered to in essence ever since, then the limitation of Bridge Canyon Reservoir to an elevation that will not encroach on that protected area should be continued, for the following points are clear, viz: A higher elevation would substantially alter natural conditions and injuriously affect the natural scenery along the Colorado River as far as the backing up of the water extends, for the sake of an exclusively economic gain, in direct contradiction of that policy. The conclusion above stated is not invalidated by the fact (a) that the impairment of natural scenery within the supposedly protected area would be relatively limited in extent in comparison with the entire area of the Grand Canyon that is supposedly protected, and would probably be observed by no more than a small fraction of the people who visit various parts of that entire area in order to enjoy its scenery, and (b) that the economic gain would be relatively large.

If, on the other hand, it is decided that the justifying reason for existence of a national park extending into the canyon downstream from Tapeats Creek is not that of protecting, in conjunction with the Forest Service, natural conditions and scenery in the Grand Canyon from rim to rim, but merely to protect Havasu Canyon Unit and adjacent areas *south* of

the river; then the logical procedure would be Congressional action making a marginal modification of the present boundary of the park west of the Tapeats Creek watershed, shifting it from the north bank of the river to a contour on the south bank that would keep it clear of the prospective reservoir.

Choice between those alternative policies depends not primarily upon technical details such as have been discussed in this report, but upon broad considerations of public purpose; in the last analysis upon how much the people of the United States care about preserving the natural conditions and scenery in the portion of the Grand Canyon selected for such preservation in 1908, and whether they are able and willing to pay the economic price of such preservation.

Marble Gorge Dam.—The Marble Gorge Dam site is 15 miles upstream from Nankoweap Canyon, the northeast corner of Grand Canyon National Park. Neither a low dam, as contemplated under the Bridge Canyon Route for diversion of water to central Arizona, nor a high dam, such as the one proposed under the Marble Gorge diversion route, would be particularly objectionable from the scenic and recreational viewpoint. In either case the part of the reservoir below Navajo Bridge would be confined in the deep narrow Marble Gorge. From Navajo Bridge to Lees Ferry the lake formed by the higher dam would cover the bottom lands between the Echo Cliffs on the east and the high, vermilion cliffs of the Paria Plateau on the west. This more open body of water would be very scenic and easily accessible from United States Highway 89 which crosses the Colorado River on Navajo Bridge.

Considering only the recreational use of the proposed Marble Gorge Reservoir and the Glen Canyon Reservoir, a high dam at the Marble Gorge site, which would eliminate a dam at the Glen Canyon site, might be more suitable for recreational development and use than a low dam at that site and a high dam at the Glen Canyon site. The Glen Canyon site is in a deep, sheer-walled canyon which extends upstream for a number of miles. Access to the reservoir from United States Highway 89 would be difficult, and there is little or no land suitable for development of recreational facilities adjacent to the water.

Kanab Tunnel and Power Plant.—The proposal to divert the main flow of the Colorado River from just above the Marble Gorge Dam to a power plant on the Colorado River near the mouth of Kanab Creek by means of a 44.8-mile tunnel under the Kaibab Plateau would be infinitely more serious in its effect upon Grand Canyon National Park than that resulting from the construction of Bridge Canyon Dam. According to the preliminary plans of the Bureau of Reclamation, the Kanab Power Plant would utilize for power generation most of the water available from the Colorado River in excess of the 1,000 second feet released through the Grand Canyon National Park, which is entirely inadequate for scenic purposes. The tunnel and power plant would be designed for a maximum discharge of 13,000 second feet.

The average discharge of the Colorado River at Bright Angel Creek was 17,720 second feet for a period of 19 years—1922-41. The maximum discharge during that period was 127,000 second feet and the minimum 700 second feet. The gage height at the maximum was 29.25 feet and at the minimum —0.70 feet. (Reference Geological Survey Water-Supply Paper 929.) The 1,000 second feet which would be permitted to flow through the national park section of the Grand Canyon under the plan proposed would be only slightly more than the minimum flow of the past 23 years, and less than one-seventeenth of the average flow. The minimum flow in 1941 was 4,300 second feet (gage height 2.61 feet), more than four times the amount proposed.

This stringent limitation on the volume of water permitted to flow through Grand Canyon between Marble Gorge Dam and Kanab Creek would greatly alter the character of the river and natural conditions in the bottom of the canyon through Grand Canyon National Park, that portion of the Grand Canyon which has been set apart since 1908 for preservation of the noneconomic values of its unique and inspiring scenery.

With the construction and operation of the Kanab Tunnel and Power Plant, the Colorado no longer would be a great river grinding the Grand Canyon ever deeper, but a man-controlled stream

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Figure 72.—View across the inner gorge of the Colorado River from Bridge Canyon.

Figure 73.—Where United States Highway 89 crosses Marble Gorge—Paria Plateau in the background. *(Air photo)*

Figure 74.—Mount Dellenbaugh from the rim of Green Springs Canyon, Shivwits Plateau.

which could be turned on and off at will. In this section of the Grand Canyon, contrasting sharply with the section of the canyon which would be inundated by the Bridge Canyon Reservoir, the river is visible from numerous points on the upper rim and well-used trails provide access to and along it.

The Kanab Creek diversion proposal would, in effect, take away from the Grand Canyon the very agent that created it; the remaining trickle would be sham and mockery in comparison to the once great force that carved the canyon—the Colorado River. The natural river and its companion piece, the canyon, are vitally significant and interrelated elements of the whole which is Grand Canyon National Park. Without the normal flow of the river the significance and completeness of the park will be destroyed and the will of the people defeated in that the great spectacle of the Grand Canyon, as set aside by the Congress in the national park, to be preserved in its natural state for this and succeeding generations, will be seriously impaired.

SUGGESTIONS FOR DEVELOPMENT OF THE GRAND CANYON AREA

Probably the best use that can be made of the Grand Canyon area from the standpoint of the American people as a whole is to reserve and develop the entire canyon and bordering plateaus as a place for recreation, primarily of the inspirational type. To those who contend that the present development in Grand Canyon National Park is sufficient to meet this need, it should be pointed out that already increased population and travel make the developed areas in the park so crowded and congested at certain seasons that chances for rest and contemplation are virtually nonexistent. The extension of opportunities to use Grand Canyon, especially the little-known western part, would greatly help in solving the future problem of adequate space for meeting the recreational needs of an increasingly large group.

Plate 5 (in pocket) presents a broad scheme for the general development of the Grand Canyon region, suggesting locations for roads and a limited number of new recreational centers which would be desirable in connection with the recreational use of the proposed Bridge Canyon Reservoir and the western part of Grand Canyon. The development plans for Lake Mead Recreational Area, Hualpai Indian Reservation, Grand Canyon National Monument, Kaibab National Forest, and Grand Canyon National Park should be coordinated on the basis of such an over-all plan to avoid conflicting developments. No one section of this area can be properly planned without due consideration being given to the possible and desirable development of the other sections.

Roads.—At the present time most of Grand Canyon is inaccessible except by arduous pack trips. The only improved roads to the canyon rim are the south and east entrance roads to Grand Canyon National Park and the road from Jacobs Lake to the north rim. On the south side of the canyon, east-west travel is practically limited to United States Highway 66, the heaviest traveled cross-continental highway west of the Mississippi River. On the north, the improved highways make such a big loop to the north that they do not provide for east-west travel through the area. There appears to be need for an improved through road for east-west travel on both the north and south sides of the canyon. At present, administration of the area is hindered by lack of such roads and the public is able to see only the eastern end of the canyon.

Consideration should be given to a road, generally paralleling Lake Mead and the Grand Canyon, that would provide a direct connection between Hoover Dam, Temple Bar, Pierce Ferry, Bridge Canyon Dam, Peach Springs, Frasiers Well, Hualpai Hilltop, and Grand Canyon Village. Such a road would enable persons to travel through the canyon country undisturbed by the nuisances of heavy trucks, fast through traffic, billboards, roadside stands, pole lines, and fences. From such a through road, spur roads might be built to outstanding observation points and recreational centers, such as at Temple Bar, Pierce Ferry, Bridge Canyon, Diamond Creek, and Granite Park. These centers could offer overnight accommodations and operate as outfitting and informational centers from which the canyon country could be explored by foot, horseback, or by boat. They could also be sub-centers for the administration of this vast area.

The two existing main roads in the Hualpai In-

dian Reservation logically would be parts of this proposed road. The road from Peach Springs through the northwest section of the Indian reservation provides access to fine viewpoints. It could be continued down through the Grand Wash Cliffs to the Pierce Ferry Road and thence west around the White Hills to United States Highway 93. The road northeast from United States Highway 66 to Frasiers Well and Hualpai Hilltop connects with a road which continues to Anita and Arizona State Highway 64. The proposed development area above Granite Park, the high point between Prospect and Mohawk Canyons, and Yumtheska Point in Grand Canyon National Monument could be made accessible by spur roads from this section of the proposed through road.

The area north of the river west of Kanab Creek is quite remote and entirely off the beaten paths of tourist travel. Existing roads and trails, for the most part ungraded, are passable only in dry weather. Mount Trumbull, the only settlement in the area, is 49 miles from St. George, Utah, and 81 miles from Fredonia, Ariz., over very poor roads. The boundary of the Lake Mead Recreational Area on the Shivwits Plateau near Mount Dellenbaugh is 82 miles by road from St. George.

There is need for an improved road from Fredonia to Tuweap in Toroweap Valley, thence west over the Pine Mountains, through the settlement of Mount Trumbull, and around Poverty Knoll to the head of Hidden Canyon. From this point there are two possibilities. One would be to carry the road down Hidden Canyon through the Grand Wash Cliffs to Pocum Wash and then south down Grand Wash to Pierce Ferry where there would be a ferry connection with the Pierce Ferry Road south of the river. The other possibility would be to connect this east-west road at the west side of Poverty Knoll, with a north-south road running between Bridge Canyon Dam and St. George, Utah.

The Pierce Ferry-Hidden Canyon route was originally proposed, primarily for recreational travel between the north rim of Grand Canyon, Fredonia, Pierce Ferry, Kingman, and Hoover Dam, at a time when Pierce Ferry appeared to be the only place where it was physically possible to have a crossing of the Colorado River between Navajo Bridge and Hoover Dam. As it has been proposed to have a highway from United States Highway 66 to and across Bridge Canyon Dam, the continuance of that highway north to St. George is within the realm of possibility.

At the present time there are only two existing routes between the populated centers of Utah and Arizona, one by way of Las Vegas, Nev., and Hoover Dam, the other by way of Navajo Bridge. United States Highways 91 and 89 are the two major north-south highways in Utah. Near the Arizona line, United States Highway 91 becomes a southwest-northeast diagonal route to Las Vegas and Los Angeles, and United States Highway 89 swings east many miles to Navajo Bridge and then south to United States Highway 66 near Flagstaff. From United States Highway 66, United States Highway 89 and alternate Arizona State Highway 79 follow indirect courses to Phoenix.

The Arizona State Highway Department has plans for a direct diagonal highway from Phoenix to Kingman and Las Vegas. It will be an extension of United States Highway 93 southeast from Kingman through the Big Sandy Valley to Congress Junction. Should the Bridge Canyon Dam be constructed, it is logical that this road would have a branch to Hackberry on United States Highway 66. This would provide a direct route from Phoenix to the Bridge Canyon Dam.

The primary consideration in the construction of a road north from Bridge Canyon Dam would be the difficulty and expense of constructing a road from the dam to the rim of the Shivwits Plateau. It appears that it might be possible to follow along the bench of the inner gorge from the dam to Separation Canyon thence up the east side of Separation Canyon and Twin Canyon to the rim west of Mount Dellenbaugh. From there to the divide north of Wolf Hole construction would be comparatively simple. Between the divide and the Virgin River there would be a short stretch of heavy construction. The total length of the road from the dam to St. George would be approximately 105 miles.

Should Bridge Canyon Dam be constructed it is recommended that preliminary surveys be made to determine whether such a road connection between United States Highway 66 near Peach Springs, Ariz., and United States Highway 91 near St. George, Utah, is or is not practicable and ultimately desirable.

Development areas.—1. Bridge Canyon section. With the construction of Bridge Canyon Dam and a highway from United States Highway 66 to the dam, the Bridge Canyon area would become one of the major recreational centers of the region. On the basis of traffic counts on United States Highway 66 and the attendance at Hoover Dam and the south rim of the Grand Canyon in Grand Canyon National Park, it is estimated that there may be approximately 365,000 visitors annually to the Bridge Canyon area. These people would desire overlook or observation points from which they could see the dam and the canyon, a lodge and cabins, trailer space and tent camps, parking areas, sanitary facilities, docks and boats for sightseeing trips on the reservoir, a landing field for both private and commercial planes, and concession and information buildings. The spectacular canyon scenery, plus the attraction of the lake, may hold people here for extended visits. Foot and horse trails through Hindu Canyon to Meriwitica and Spencer Canyons and to Peach Spring Draw as well as to viewpoints along the rims of the canyons would probably be popular. Horses and guide service could be furnished by the Hualpai Indians.

The route selected by the Bureau of Reclamation for the highway from United States Highway 66 to the dam starts about 3.5 miles west of Peach Springs, Ariz., and runs generally north to Hindu Canyon. From the north side of Hindu Canyon a 4,000-foot tunnel would carry the road down through the divide between Hindu and Bridge Canyons. From the lower end of the tunnel the route continues down the west side of Bridge Canyon to the narrow bench above the inner gorge of the river and then winds along the bench to the dam site which is about 2.25 miles downstream from the mouth of Bridge Canyon. There would be a road across the dam to a parking area on the north side of the river.

This road down into Grand Canyon would be one of the dramatic features of the area. Turn-out parking areas should be provided wherever possible so that people may stop and enjoy the views. The turn-outs also would be useful for the heavy traffic of the construction period.

From near the upper end of the tunnel in Hindu Canyon a branch road would run west and north to the rim of the Grand Canyon directly above the dam where there is a quarry site for the crushed aggregate to be used in the construction of the dam. The construction camp site is located along this road on the high land between Bridge Canyon and Spencer Canyon.

Because of the difficulties of constructing roads to the rim of the Grand Canyon and of getting water to the rim, it is recommended that the lodge, cabins, and other recreational facilities be located on the rim southeast of the quarry site. In that location the road to the quarry and the water system serving the construction camp could also serve the recreational area. The recreational facilities should be constructed during the early stages of the project, so that they could be used both during and after the construction of the dam.

At a suitable point above the dam, provision should be made for a boat dock from which concessioners could operate sightseeing boat trips on the reservoir. Such trips would be popular because of the unusually spectacular canyon scenery.

2. Peach Springs Draw-Diamond Creek Area. At the present time Peach Springs Draw is the only place where it is possible to drive an automobile to the bottom of Grand Canyon. It would be a comparatively simple matter to construct a road down this draw from United States Highway 66 to the shore of the Bridge Canyon Reservoir where limited development of boat landings, parking areas, and other facilities for the recreational use of the reservoir could be provided. If this road were built, the Peach Spring-Diamond Creek arm of the reservoir would be the major center for boating activities on the reservoir. The precipitous banks of the reservoir in the vicinity of the dam would limit boating operations in that location. It would be possible to continue the road along the shore of the reservoir to a bench in the canyon overlooking Diamond Creek and the Colorado River. This would be an interesting location for a lodge in connection with the harbor development. Peach Spring Draw is dry except after a heavy rain in the immediate vicinity, but Diamond Creek has a continuous flow which could be used as a source of water for the development in this section.

3. Granite Park. This remote section of the Lake Mead Recreational Area and the Hualpai Indian Reservation, now practically unknown, offers canyon scenery of outstanding interest. At the

Figure 75.—Peach Springs Draw (left) joins Diamond Creek near the Colorado River. *(Air photo)*

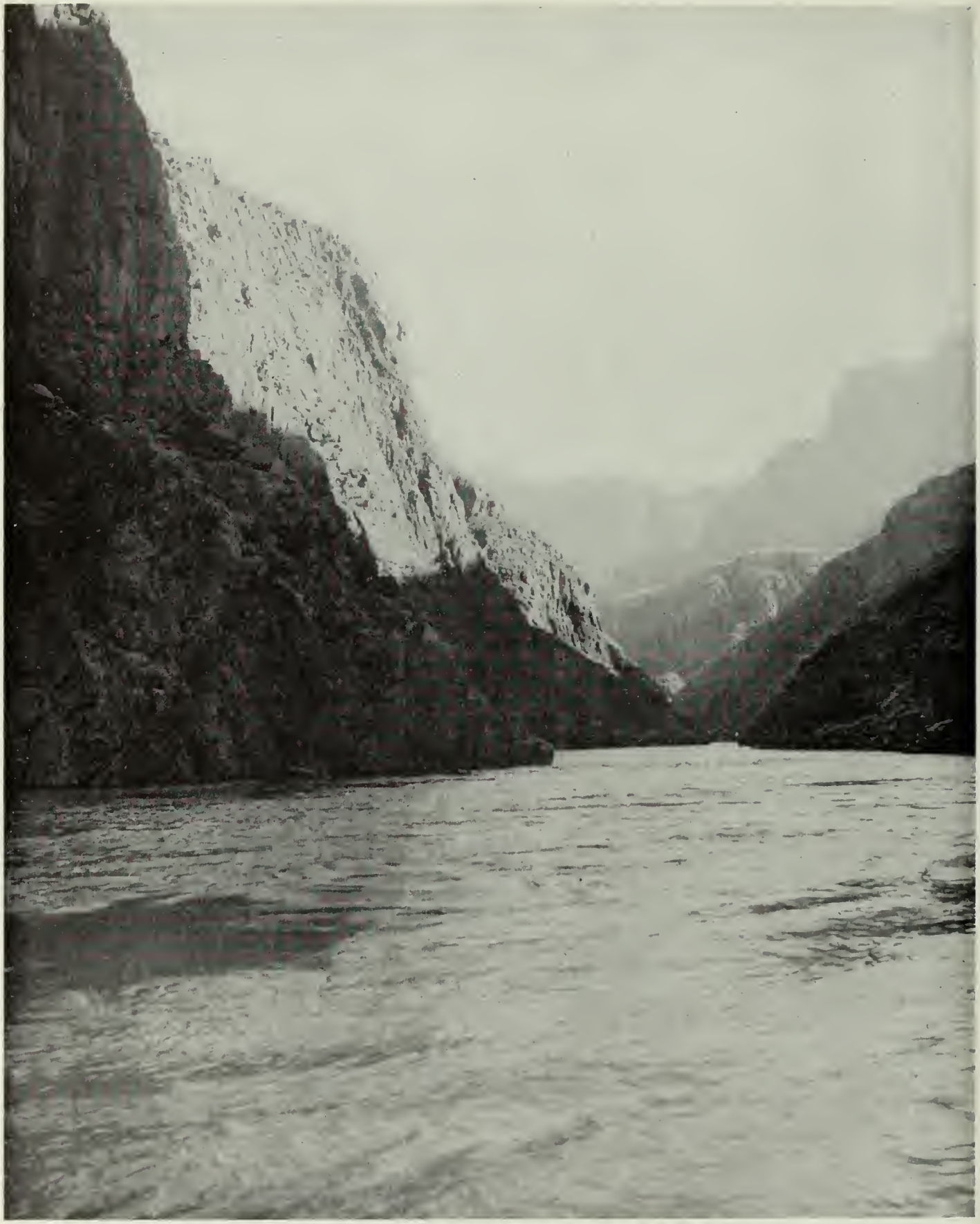

Figure 76.—The Colorado River.

present time there is an unimproved road from Frasiers Well north into Prospect Valley. The road ends about 16 miles north of Frasiers Well at a point about 17 miles south of the mouth of Prospect Canyon. The Aubrey Cliffs wall the east side of Prospect Valley while on the west side the land, thickly covered with large old piñons and junipers, slopes up to the rim of the Grand Canyon. This high rim, around 5,600 feet above the river, provides splendid views in all directions. The scene is entirely different from that of the Bright Angel section of the canyon but is considered to be equally grand. Half way down to the river is the wide red Esplanade which could be made accessible by road and might be a suitable location for a lodge. From a well-chosen point on the Esplanade, the river gorge, the reservoir, and the towering cliffs of the outer rim would be visible so that the full scale of the canyon could be comprehended. It is difficult to appreciate the size of the canyon from the upper rim or from the bottom.

Granite Park is about 28 miles upstream from the Bridge Canyon Dam site and 17 miles above Diamond Creek. Boat trips on the reservoir and horseback trips along the Esplanade from this development center would be wonderful experiences.

4. Toroweap-Whitmore Wash area. The Toroweap-Whitmore Wash area should attract more visitors than any other section on the north side of the Colorado River west of the Kaibab Plateau because of the variety of spectacular scenic and geologic features and the fact that it can be made accessible both by road and by air.

It has been suggested that a loop road, connecting with the main east-west road previously suggested, extend down Toroweap Valley around the south end of the Pine Mountains into Whitmore Wash to the little settlement of Mount Trumbull. From near Mount Trumbull a spur road following an existing automobile trail could be built to the end of Whitmore Point, overlooking Whitmore Canyon, Parashont Canyon, and the inner gorge of the Colorado River.

Due to the scarcity of water in this country, the best location for a lodge would appear to be at the upper end of Whitmore Wash near Big Spring Wash. To the north, up Big Spring Wash, green forest-covered hills rise to Mount Logan. On the east Mount Emma and other volcanic cones form the skyline more than 3,000 feet above the valley. Great, black lava flows descend from the peaks down to the center of the valley around and over sheer cliffs of Coconino sandstone and Kaibab limestone. Farther down the wash, or canyon, are the cinder cones and other formations previously mentioned. In the canyon to the west are numerous evidences of early Pueblo Indian occupation. Most important, however, is the fact that a good flow of water is available at this point. Years ago it was piped here from Big Spring, located high on the slope of Mount Logan.

From the road in Whitmore Wash a spur road could be built on the Esplanade around the end of Whitmore Point to observation points on the inner rim of Parashont Canyon and the rim of the inner gorge of the Colorado River. Trails from the lodge and various points along the roads might lead to the many points of interest such as the Pine Mountains, the lava flows, and the canyons along the reservoir.

It is possible that a suitable landing place for boats can be found either in Whitmore Wash or Twin Canyon which joins Whitmore Wash about a half mile from the Colorado River. If Twin Canyon could be made easily accessible from the reservoir, it would be a delightful place for a camp. The bottom of the canyon presents the appearance of a peaceful, grassy meadow and there is water nearby.

Development on the north side of the Grand Canyon should, it is believed, include the improvement of a spur road from Fredonia-Tuweap Road to the vicinity of Boysag Point.

5. Shivwits Plateau area. The use and development of this area will depend to a large extent upon whether a road is built from Bridge Canyon Dam to St. George, Utah. The chief attractions of the area are the fine views of the Grand Canyon from such points as Price Butte, Sanup Point, Twin Point, and Horse Point. On an average of 5 miles from the Colorado River the plateau ends abruptly with almost sheer walls 1,000 to 1,300 feet high. Below the cliffs is a wide bench, the Esplanade, sloping down to the inner gorge of the Colorado which varies from 2,000 to 3,000 feet in depth.

Sanup Point, the extreme south end of the plateau, rises about 4,800 feet above the river to an elevation of 6,000 feet. Deep side canyons cut back into the plateau, and four prominent knobs—Blue Mountain, Price Butte, Mount Dellenbaugh, and Poverty Knoll—rise above the general level of it.

A road northward from Bridge Canyon Dam might reach the rim of the plateau at the head of Twin Canyon, southwest of Mount Dellenbaugh. A short distance from the rim a cross road could lead east and south to Price Butte and west and south to Twin Point and Horse Point. Recreational headquarters for the Shivwits Plateau area might logically be located near the crossroads on the rim of Twin Canyon. There is a nice growth of ponderosa pine in this section and water is available.

If a road from Bridge Canyon Dam to St. George is not built, no development for recreational use of the Shivwits Plateau area is recommended. The present trails will suffice for those who wish to explore this remote area.

Canyon Lands of Southeastern Utah

LOCATION

Broadly speaking, the region considered is the portion of the Colorado River Basin between Lees Ferry, Ariz., the Dewey Dam site on the Colorado, and the town of Green River, Utah, on the Green River, excluding the San Juan River Basin above Bluff, Utah, and the high plateaus along the west side of the basin.

The region is roughly bounded on the east by State Highway 47 and United States Highway 160; on the north by United States Highway 50; on the west by State Highways 10, 72, 24, the road through the Dixie National Forest from Torrey to Boulder, the county road from Boulder to Escalante, Utah, State Highways 23, 22, and 12, and United States Highway 89; and on the south by United States Highway 89, and the road through the Indian reservations from Tuba City, Ariz., to the Utah State line where it connects with Utah State Highway 47.

This report is especially concerned with the vast, colorful land of deserts, mountains, canyons, plateaus, and buttes that lie within the fringe of settlements and the connecting roads—more than 20,000 square miles, in which probably less than 200 people have their permanent residence, exclusive of the Indians on the Navajo Reservation. Men running cattle and sheep in the area live in the bordering settlements and go out to their stock occasionally by truck and horseback. The sheepherders camp here during the winter and move to higher mountain pastures for the summer. (Plate 9 in pocket.)

PRESENT ROADS AND TRAILS

This region is part of the largest section in the United States in which there are no improved roads. Within the belt there are no improved roads except the short spur to Henrieville, the road in Bryce Canyon National Park, and in the settled section around Price. Two hundred and ninety miles of the 800 miles of roads forming the belt are unimproved.

State Highway 24 crossing the northwest portion of the area from Green River to Fruita in Capitol Reef National Monument is only a fair-weather trail, as is State Highway 95 from Blanding to Natural Bridges National Monument. The remaining roads in the area are truck trails constructed by the Grazing Service (now the Bureau of Land Management) or the local people to give access to cattle and sheep camps, mines, and oil prospects. Between Lees Ferry and Moab on the Colorado and the mouth of the San Rafael River on the Green River there is only one place where it is possible to drive to the rivers without extreme difficulty. The old trail down North Wash Canyon and up White Canyon to Blanding has been improved. The lower end of the trail from Escalante to Hole in Rock, a distance of about 6 miles, has not been used since the Hole in Rock pilgrimage in 1939, except by men on horseback. There has been a trail from Notom on State Highway 24, down Halls Creek to within a few miles of the river, but this was not passable in 1943 beyond a point 18 miles from the river. In the spring of 1943, trucks were driven from Kanab to the site of the old town of Paria, thence southeast to Lone Rock on Wahweap Creek, about 8 miles west of the point where the Colorado River crosses the Utah-Arizona State line.

On the east side of the Colorado it is reported that an automobile has been driven to a point west of the Clay Hills on the old Mormon Trail which runs from near Natural Bridges National Monument southwest toward Hole in Rock.

Fourteen miles north of Monticello there is an unimproved road leaving United States Highway 160 which gives access to the north side of the Abajo Mountains and Indian Creek Valley. Following this road down Indian Creek and around the

north side of North Six-Shooter Peak, it is possible to drive, under favorable conditions, to the northeast edge of the spectacular Needles area, about 7 miles air line southeast of the junction of the Colorado and Green Rivers.

Half way between Moab and United States Highway 50 there is a truck trail leading to the west which gives access to the high plateau between the Green and Colorado Rivers. It is possible to drive to within 1 mile of the southern tip of the plateau. This point is about 3 miles from both rivers, approximately 2,400 feet above them, and 8 miles almost due north of their junction. Branch trails lead to Upheaval Dome on the west side of the plateau overlooking the Green River Canyon, and Dead Horse Point on the east side. Dead Horse Point is within a mile horizontally of the Colorado River and approximately 2,000 feet above it. Unquestionably the most spectacular and far-reaching views of the Colorado and Green River Canyons obtainable by automobile at the present time are from these trails on the plateau between the rivers. The only other point, now accessible by automobile, which rivals these, is Lands End at the southeast edge of the plateau between the Green and Dirty Devil Rivers. Excellent views of the canyon country are obtained along the last few miles of the trail from Hanksville to Lands End and it is about a mile walk from the end of the trail to Lands End, a high point on the rim of the plateau, only 5 miles from the Colorado River and more than 3,000 feet above it.

RECREATIONAL AND RELATED VALUES OF THE REGION

Monument Valley has been referred to as "The land of room enough and time enough." To this could be added beauty and thrills, and mystery enough, all of which are applicable to the Colorado River country of southeastern Utah. It is stark realism and mystical surrealism. Trying to make a living raising cattle on the Green River Desert or driving an automobile across its deep sandy wastes on a hot afternoon, one suffers the torments of hell, and curses the country and the reasons that brought him there. However, as the purple shadows begin to lengthen across the gold and red sands, as the towering buttes take on a rosy hue, and distant purple mountains are silhouetted against a royal blue sky, it becomes a dream world of marvelous beauty. Searching across barren rocks for a water hole in summer, or climbing a steep, rocky, snow-covered trail up a canyon wall in winter, you realize why no humans and few animals make their homes there; and yet, standing on Horse Mountain, or Dead Horse Point, or Lands End, or camping near a spring on the Kaiparowits Bench with the canyon of the Colorado below, and Navajo Mountain rising from its fluffy sandstone base across the way, you wonder why so few people have made their way to these places. You are exalted spiritually, but dwarfed by the scale of the scene. Your eye is attracted quickly from the nearby rocks to the mountaintops 40 to 70 miles away: across

Figure 77.—Monument Valley.

miles of bare, pink, red, buff, and white sandstone; down canyons 2,000 feet deep; and up buttes 1,000 feet high. All is yours—20,000 square miles or more—and yet, to approach on foot or horseback even one of the nearby canyons is a giant's task.

It is a land of the unusual in color and form, of great natural bridges, monuments, spires, intricately twisting canyons, mammoth terraces with sheer walls a thousand or more feet high, and rock forms that resemble castles and cathedrals. But the most impressive feature is that of space. Not the monotonous space of the Great Plains, but dramatic, colorful space accentuated by these varied land forms and the high mountains to the east and west and the broad sweeps of unfenced range.

From high points the region appears as a great, deeply eroded plain from which rise three beautiful mountain masses. The LaSals to the northeast rise to 13,089 feet above sea level; the Abajos in the east central part rise to 11,445 feet; and the Henrys in the west central part rise to 11,485 feet. To the southwest, the Kaiparowits Plateau stretches southeast from the high plateaus for 50 miles, at the 7,000-foot level, as far as Navajo Mountain (elevation 10,416 feet) which stands alone on the south side of the Colorado River. East of Navajo Mountain, the monuments of Monument Valley standing against the sky may be seen from great distances. To the north the Book Cliffs, with the Roan Cliffs above, form the skyline. To the northwest the San Rafael Swell, and beyond and above it the Wasatch and Fish Lake Plateaus, end the view. West of the Henrys, Boulder Mountain and the Aquarius Plateau, elevations 10,000 to 12,250 feet, respectively, blend into the western end of the Kaiparowits Plateau to form the distant skyline. To the south and southeast is a horizon less definite and broken by great mesas and mountain peaks. From the south end of Elk Ridge, which lies to the west of the Abajo Mountains, may be seen the Carrizo Mountains, Pastora and Zilbetod Peaks just south of the four corners, and Ute Peak southwest of Cortez, Colo. East of the Abajo Mountains, the great sage plain stretches on and on to the snow-covered peaks of the La Plata and San Miguel Mountains in Colorado. East of the La Sal Mountains is a jumble of canyons and mesas terminated by the Uncompahgre Plateau.

Down through the center of all this, majestically flows the Colorado River in its great canyon that starts just below the mouth of the Dolores River and continues almost unbroken to the Grand Wash Cliffs, a distance of 590 miles, the first 285 miles of which are in Utah. From Moab to the junction with Green River, the Colorado flows along a fairly smooth bed, easily navigable by small boats. From the junction to Mille Crag Bend are 40 miles of some of the roughest water of the entire canyon section of the river, hence, Powell's name for this section—Cataract Canyon. From Mille Crag Bend to Lees Ferry the river flows quietly between monumental walls. The beauty of the scenery and quiet waters suggested to Powell the name Glen Canyon. Because of the depth of the canyon, little is seen from the river, except the immediate canyon walls. Powell and other river adventurers had to be continually scaling the canyon walls in order to get an idea of the country they were passing through. From the tops of the river canyon walls the scene is quite different from that obtained from the higher observation points on the plateau. For example, standing on the rim of the river canyon 1,200 feet directly above the junction of the Green and the Colorado, the great mountain masses and the plains are not visible; instead, there are the thousands of little mountains, buttes, spires, domes, and walls formed by the erosion of the great plain that forms the skyline. You are down in another world surrounded by a complicated jumble of pink, buff, and red sandstone formations, fantastic and beautiful. To the west, north, and east above the general level of this land of standing rocks, two great irregularly shaped terraces rise about 2,000 feet. Here and there, rising from the dark red lower terrace, are huge buttes and smaller walls and spires of the same color. The face of the upper terrace is sheer and of an orange-brown tone, which has given it the name, Orange Cliffs. To the south, on the east side of the river, an intricate system of parallel faults and erosion have created the unique Needles area which blends into formations similar to the Standing Rocks. These in turn build up gradually to Elk Ridge which runs generally north and south at an average elevation of 8,600 feet. Horse Mountain, the high point at the north end of Elk Ridge, rises 5,587 feet above the Colorado River to an elevation of 9,202 feet above sea level.

Below Cataract Canyon the scene changes; great

Figure 78.—Junction of Green and Colorado Rivers—the Colorado River flows from right to left. *(Air photo)*

side canyons run back into the mountains on the east and west. The terracing is more broken and disappears entirely in some sections. From the river at Hite can be seen Mount Holmes, 6.5 miles away rising 4,500 feet above the river to an elevation of 8,000 feet above sea level, and Mount Ellsworth, 9 miles away, rising 5,800 feet above the river to an elevation of 8,250 feet above sea level. From the Escalante River to below Hole in Rock the Navajo sandstone forms a ridge along the west side of the river canyon. Climbing up from the river to this ridge one finds remarkable views in all directions. The Red Rock Plateau of apparently limitless barren sandstone obscures the view of the Abajo Mountains and the country to the east. But to the north, over the deeply carved back of the Waterpocket Fold, loom the peaks of the Henry Mountains and the rim of the plateau between the Colorado and Dirty Devil Rivers almost 70 miles away. To the northwest for 50 miles stretches the Escalante Valley, walled on the southwest side by the Straight Cliffs of the Kaiparowits Plateau. From the base of the Straight Cliffs the desert rises gradually to the northeast to the Waterpocket Fold and the Circle Cliffs. In the long twisting gash in the bare sandstone along the southwest side of the Waterpocket Fold is the Escalante River. Beyond the upper end of the desert can be seen the high land of the Aquarius Plateau, 70 miles away. To the south the lone peak, Navajo Mountain, dominates the view.

After the river winds down between the Kaiparowits Plateau and Navajo Mountain it comes out into more open country. The immediate canyon walls are lower and the land steps up gradually in great wide benches. This continues until the river reaches the Paria Plateau and swings around the east end of the plateau in a deep narrow canyon. It is in this more open stretch of the river that Escalante[1] found the Old Indian Crossing. If the Glen Canyon Dam raised the water to the elevation suggested by the Bureau of Reclamation, the widest expanses of water would be in the vicinity of the Crossing of the Fathers. Barry Goldwater of Phoenix, Ariz., stated in an article which appeared in Desert Magazine describing a trip down the river from Green River, Utah, to Hoover Dam: "Glen Canyon has always been synonymous in my mind with the unusual, the beautiful and the historic."

[1] Silvestre Velez de Escalante (1768-79), Spanish Franciscan, known chiefly as a missionary-explorer in New Mexico and adjoining regions about the beginning of the last quarter of the eighteenth century.

OUTSTANDING AND UNIQUE SCENIC SECTIONS

Within the area there are certain sections where the various types of scenery and other recreational interests reach a climax; where, after traveling for miles through this fascinating country, you come to a section that startles you by its grandeur or unusual character.

Grays Pasture-Junction Butte area.—Grays Pasture is such an area. It includes all of the plateau between the Colorado and the Green Rivers, south of the Neck, a 50-foot-wide isthmus connecting Grays Pasture and the highland to the north. At the present time this is one of the most accessible sections from which to view the great panorama of the area and the canyons of the Green and Colorado Rivers above their junction. Dead Horse Point on the east rim is the best known and probably one of the finest points from which to view the Colorado River winding through its amazing canyon 2,200 feet below. Upheaval Dome, on the west rim of the plateau, is the most unusual and dramatic geologic feature in southern Utah. It resembles a multicolored crater 2 miles in diameter, encircled by a ridge of red sandstone. From the southwest rim of the dome one obtains impressive views of the Green River Canyon and all of the high land in every direction—the Roan Cliffs to the north, La Sal Mountains to the east, Abajo Mountains to the south, and Henry Mountains to the southwest.

Elk Ridge.—On the east side of the Colorado, in the La Sal National Forest between Indian Creek on the north, and White Canyon on the south, and west of the Abajo Mountains, is a section which is certain to become nationally famous for its great variety of unusual scenic interests. Elk Ridge, running generally north and south at an average elevation of 8,500 feet, with high points at the north and south ends reaching over 9,000 feet, is the dominant topographic feature. From Elk Ridge great canyons start down toward the Colorado—White Canyon, Woodenshoe Canyon, Peavine

Figure 79.—Colorado River from Deadhorse Point—the highland forming the skyline is Grays Pasture.

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Figure 80.—Shafer Canyon from Deadhorse Point during a January storm.

Figure 81.—View southeast from Upheaval Dome.

Figure 82.—View south from Upheaval Dome.

Figure 83.—View southwest from Upheaval Dome—white rim sandstone edges the wide red Moenkopi bench. The slopes between the bench and the orange-brown Wingate sandstone cliffs are gray Shinarump and various colored Chinle formations. Above the cliffs is light buff Navajo sandstone.

Figure 84.—Monument Canyon and Indian Creek country east of Colorado River from Junction Butte point.

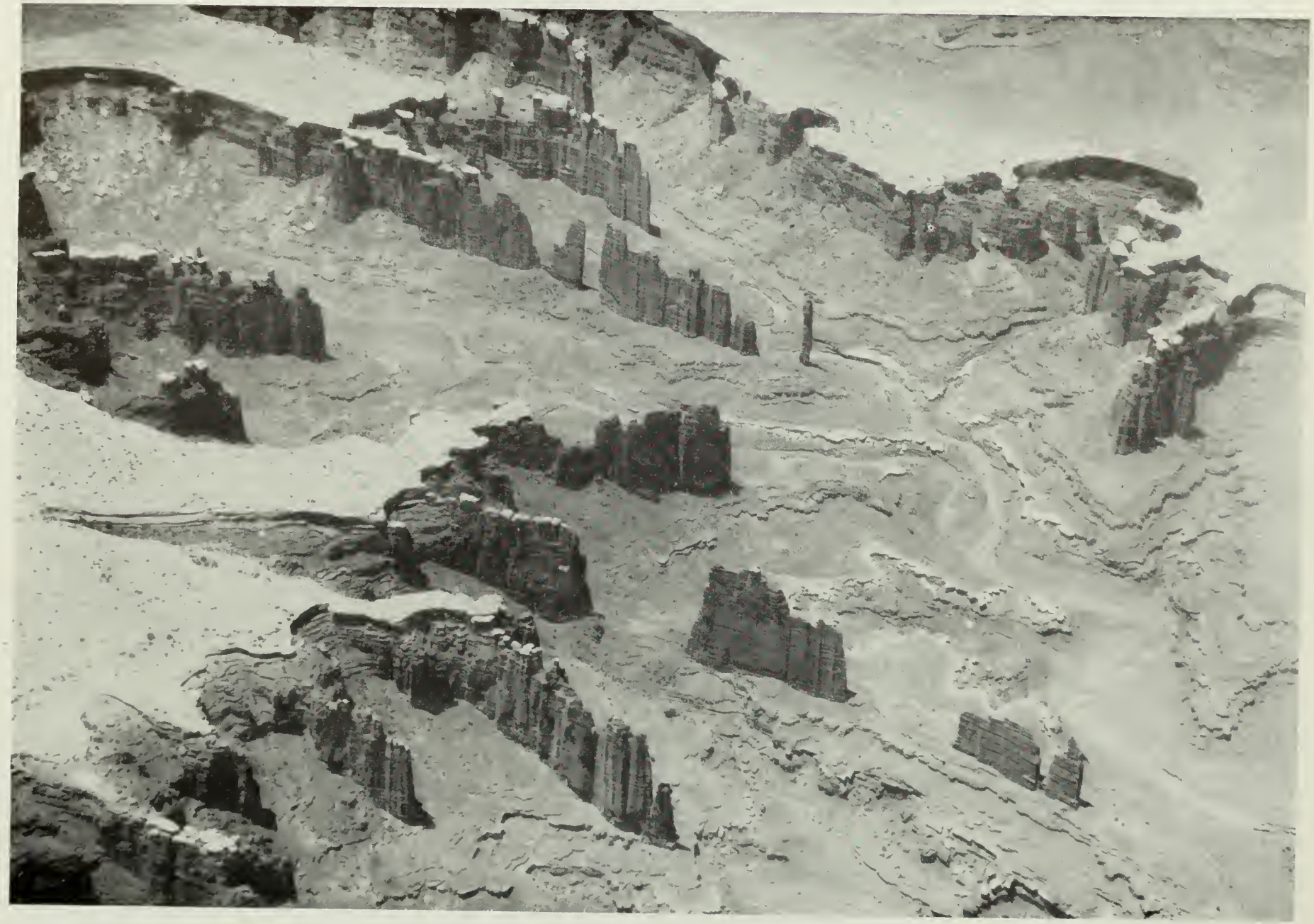

Figure 85.—White rim sandstone caps the dark red towers of Monument Canyon. *(Air photo)*

Figure 86.—Junction Butte from the rim of Green River Canyon near the junction of the Green and Colorado Rivers.

Canyon, Dark Canyon, Fable Valley, and Gypsum Canyon. Near their junction, Dark and Woodenshoe Canyons are 2,000 feet deep, while the lower end of Gypsum Canyon is more than 2,300 feet deep, and at least one high point on the rim of Gypsum Canyon within a mile of the Colorado River is 3,527 feet above it. From the pine and aspen forested Elk Ridge there are grand views down into the canyons on all sides and out over Beef Basin and the Needles to Junction Butte to the northwest; over the Grand Gulch Plateau, Natural Bridges National Monument in White Canyon, the Tables of the Sun, and Red Rock Plateau to Navajo Mountain in the southwest; down 2,200 feet into Cottonwood Canyon which separates Elk Ridge from the Abajo Mountains and up 2,600 feet to Abajo Peak, elevation 11,357 feet. Elk Ridge is a delightfully cool forest island in a rough iridescent sea of deserts and canyons.

Needles area.—North of Elk Ridge lies the Indian Creek country which revolves around North Six Shooter, a great monolithic guide post. West of North Six Shooter and southeast of the junction of the Colorado and the Green Rivers is a fantastic section of curiously eroded and faulted red, buff, and white rocks called the Needles. On the ground it is a seemingly endless labyrinth of little valleys above which tower great sandstone domes and pinnacles. From the air it is an amazingly intricate pattern of green, yellow, buff, pink, and red.

On August 23, 1859, Dr. J. S. Newberry, geologist to the MacComb Expedition, wrote the following description of this area as seen from the top of a butte located about a mile south of the mouth of Indian Creek:

> The great cañon (Grand Canyon) of the lower Colorado, with its cliffs a mile in height, affords grander and more impressive scenes, but those having far less variety and beauty of detail than this. From the pinnacle on which we stood the eye swept over an area some fifty miles in diameter, everywhere marked by features of more than ordinary interest; lofty lines of massive mesas rising in successive steps to form the frame of the picture; the interval between them more than 2,000 feet below their summits. A great basin of sunken plain lay stretched out before us as on a map. Not a particle of vegetation was anywhere discernible;

Figure 87.—Junction Butte and Grays Pasture Plateau from south of the Needles.

Figure 88.—Dark Canyon—looking east over Elk Ridge to the Abajo Mountains. *(Air photo)*

Figure 89.—Arch Canyon—looking northwest over Elk Ridge. *(Air photo)*

Figure 90.—White Canyon, Tables of the Sun, and Navajo Mountain from vicinity of Natural Bridges National Monument. *(Air photo)*

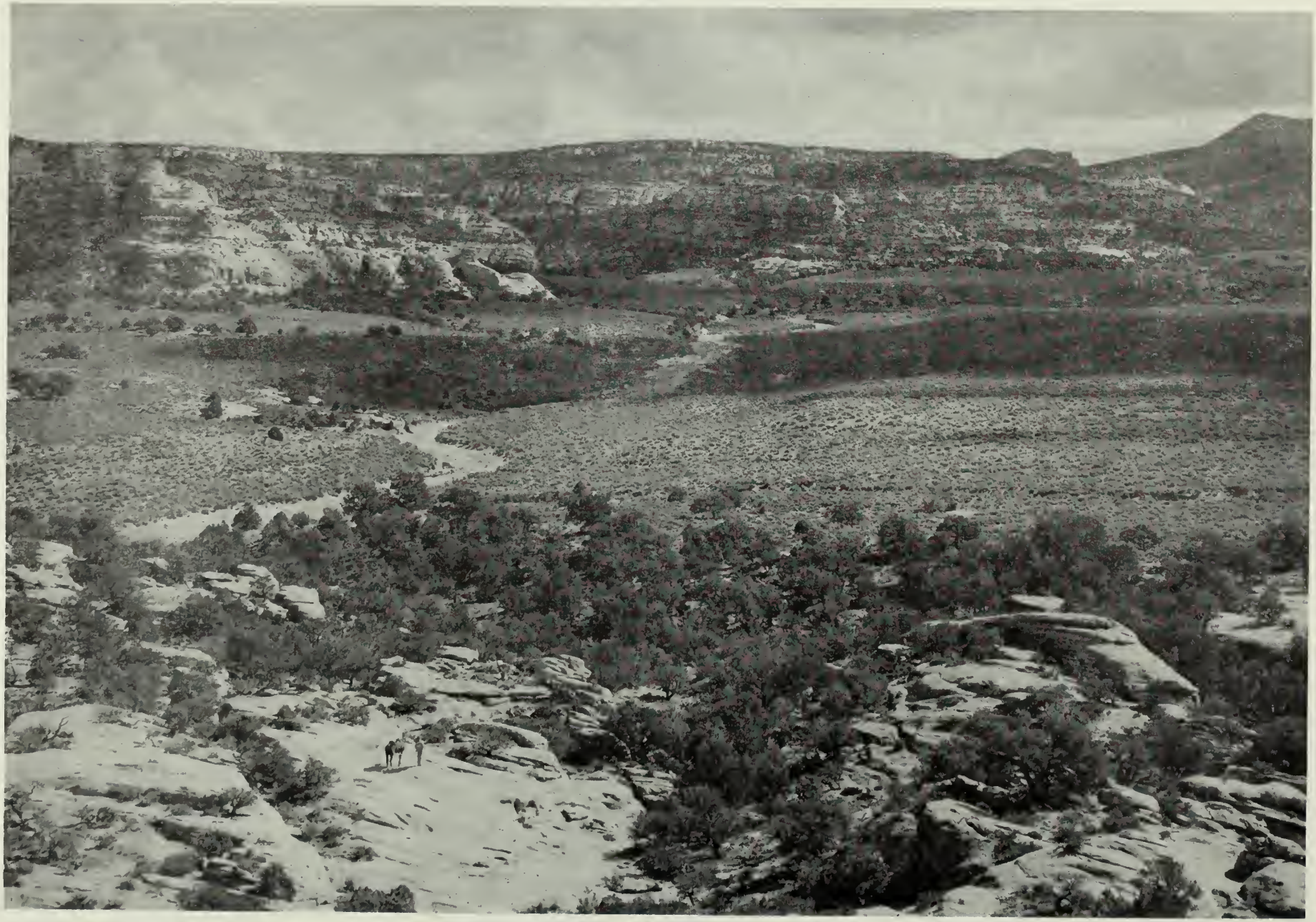

Figure 91.—Beef Basin. Horse Mountain, the north end of Elk Ridge, is at upper right corner.

Figure 92.—The approach to the Needles labyrinth is from Indian Creek. La Sal Mountains are in the distance. *(Air photo)*

Figure 93.—The Needles area—looking northeast over Indian Creek Valley. *(Air photo)*

Figure 94.—The Needles area from the air is an intricate pattern of green, yellow, buff, pink, and red.

Figure 95.—The Needles area is carved out of Cutler sandstone.

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Figure 96.—Land of Standing Rocks—looking northwest toward Elaterite Butte and Lands End Plateau (upper left) from the junction of the Green and Colorado Rivers. (*Air photo*)

nothing but bare and barren rocks of rich and varied colors shimmering in the sunlight. Scattered over the plain were thousands of the fantastically formed buttes to which I have so often referred in my notes; pyramids, domes, towers, columns, spires, of every conceivable form and size. Among these by far the most remarkable was the forest of Gothic spires, first and imperfectly seen as we issued from the mouth of the Cañon Colorado. Nothing I can say will give an adequate idea of the singular and surprising appearance which they presented from this new and advantageous point of view. Singly, or in groups, they extend like a belt of timber for a distance of several miles. Nothing in nature or in art offers a parallel to these singular objects, but some idea of their appearance may be gained by imagining the island of New York thickly set with spires like that of Trinity Church, but many of them full twice in height. Scarcely less striking features in the landscape were the innumerable cañons by which the plain is cut. In every direction they ran ramified deep, dark, and rugged, impassable to everything but the winged bird. Of these the most stupendous was that of Grand River, which washes two sides of the base of the pinnacle on which we stood, a narrow chasm, as we estimated, full 1,500 feet in depth, into which the sun scarcely seemed to penetrate. At the bottom the whole breadth of this cañon is occupied by the turbid waters of Grand River, here a sluggish stream, at least with no current visible to us who were more than 2,000 feet above it. In this great artery a thousand lateral tributaries terminate, flowing through channels precisely like that of Labyrinth Creek; underground passes by which intermittent floods from the distant highlands are conducted through this country, producing upon it no other effect than constantly to deepen their own beds.

Lands End area.—West of the junction of the Green and Colorado Rivers is Lands End, appropriate name for a low knob at the south end of a finger of the high plateau standing between the Dirty Devil River and the Colorado. The name might well apply to the entire 9.5-mile remnant of plateau land between the knob and Observation Rock. Driving south from Green River. Utah, through seemingly endless stretches of sand and rock in places covered with blackbrush or grasses, in places barren, you note that the ground is gradually rising. Occasionally there is a view of the La Sals to the east or the Henry Mountains to the west, or a glimpse of the heads of canyons leading down to the Green River. There are 60 miles of this to Robbers Roost, a large shallow open bowl, which is said to have provided the perfect secluded range for cattle stolen from the early Mormon settlers. It was reputedly the hang-out of Butch Cassidy and his gang of outlaws. Southeast of the Roost, the land continues to rise, piñon and juniper appear, and canyons heading near the road lead off to the right and the left. Fourteen more miles and you are at French Seep. Observation Rock stands directly ahead on the rim of a world of great terraces, canyons, and strangely carved rocks that surrounds the junction of the rivers.

North of Observation Rock is Cleopatras Chair, a high block of Navajo sandstone sitting on the edge of the upper terrace, commanding a view of the Stillwater Canyon of the Green, Junction Butte, Upheaval Dome, and the La Sal Mountains far beyond.

At French Seep the trail turns south and winds its way along the top of the piñon and juniper covered remnant of plateau. The winding of the trail provides alternate views into the many fingers of Happy Canyon and out over the great canyon of the Colorado. Although lower than Elk Ridge, this too is an island of green forest surrounded by a fantastically shaped and colored sea of desert; an excellent place from which to view the canyons of the Colorado and the Green Rivers or for a base camp for exploring expeditions down into that beautifully weird "Land of Standing Rocks" or down to the edge of the sheer-walled Cataract Canyon 2,000 feet deep. Lands End is one of those satisfying far-off places you want to visit again.

Hite area.—The Dandy Crossing or ford of the Colorado River, later replaced by Hites Ferry, greatly facilitated the extension of early Mormon colonization of the San Juan country of southeastern Utah. The great early activity in placering

Colorado River gravel bars for gold occurred in the vicinity and down river from Dandy Crossing and Hites Ferry.

Present access to Hite is by pioneer road down North Wash through impressive red sandstone cliffs and monuments to the Colorado, then for 6 miles along the narrow sandstone ledge on the west side of the river to Hite. Here one finds in a severe, rugged country the Chaffins living in a place of beauty and tranquility. Above the Orange Cliffs to the northwest the high and formidable Henry Mountains dominate the scene.

Glen Canyon Reservoir will inundate the area, but there is a proposal to preserve this natural Colorado River scene of Mormon pioneering as a scenic and historic area.

The Utah State Highway Commission and the Public Roads Administration have proposed a road joining Capitol Reef and Natural Bridges National Monuments, Arch Canyon and Blanding, and crossing the Colorado River by suspension bridge near the mouth of the Dirty Devil River. This crossing is 7 miles above Hite and 112 miles from Moab Bridge. It is 174 miles above Navajo Bridge at Marble Gorge. This will be the only through road in the 20,000 square miles of Utah's Canyon Lands.

Hole in Rock area.—From the little town of Escalante, Utah, the Straight Cliffs of the Kaiparowits Plateau point the way and Navajo Mountain marks the center of interest in the Glen Canyon section of the Colorado River country. Here is scenery, bold, stark, gigantic. Natural bridges, 300 feet high, are lost in the canyons. Great domes of sandstone around Navajo Mountain appear as a downy cushion base for the mountain. The views from the plateau and from Navajo Mountain are breathtaking. Navajo Point at the southeast end of Kaiparowits Plateau, elevation 7,500, is 5 miles horizontally from the Colorado River and 4,000 feet above it. The crest of Navajo Mountain, 8 miles east of the Colorado, is 7,015 feet above the river. A few miles to the southwest is the Crossing of the Fathers where Escalante made his arduous crossing in 1776. It is one of the few Indian crossings and the first crossing used by the Mormon missionary, Jacob Hamblin, on his early trips to the Zuni Pueblos. A few miles to the north is Hole in Rock where the Mormon settlers bound for the San Juan Valley made their heroic crossing of the 1,400-foot-deep canyon of the Colorado in the winter of 1890, a crossing so difficult it was only used once and abandoned for the easier Dandy Crossing at Hite.

It is a land of natural bridges. Rainbow Bridge, the largest and most beautiful, and three others are found in the canyons around the base of Navajo Mountain. At least six fine bridges are known to exist in the twisting half-domed tributary canyons of the Escalante River. Two in Coyote Canyon, one in Willow Creek, and one in Davis Canyon have been visited by members of the survey staff. Another said to be about as large as Rainbow Bridge, was seen by the Nevills Expedition in 1940 and named by them "Gregory," in honor of Dr. Herbert Gregory, a noted American geologist.

Music Temple, famous resting point for all river expeditions since Powell's first party stopped there in 1869 for a night of singing and carved their names on the wall, is on the left side of the river between the mouth of the San Juan and Arch Canyon. North of the Escalante River Canyon is the Waterpocket Fold.

There are two unimproved roads leading to this section. From the Navajo country to the south and east there is a road to Rainbow Lodge located on the south slope of Navajo Mountain. From the lodge an 18-mile trail leads to Rainbow Bridge. From State Highway 23, the unusually scenic road between the towns of Escalante and Boulder, an automobile trail runs southeast along the base of the Straight Cliffs for 51.3 miles to Sody Tank, 6 miles west of Hole in Rock. There is a horse trail from Sody Tank up the face of the Straight Cliffs to the top of the Kaiparowits and to Hole in Rock.

Wahweap area.—The old trail from Kanab to the Crossing of the Fathers crosses Wahweap Creek and Warm Creek almost on the Utah-Arizona State line and then swings northeast across Cottonwood Canyon to the crossing at Kane Creek. In this highly colored desert section of buttes, mesas, and canyons would be the only wide water of the lake formed by the potential Glen Canyon Dam. At spillway level, 3,528 feet, the lake would extend 7 miles up Wahweap Creek, spreading out north of the State line to form a body of water about a mile wide and 2 miles long. Two miles northeast of Wahweap Bay would be Warm Creek Bay 4

Figure 97.—Southeastern end of the Kaiparowits bench and Navajo Mountain from near Sody tank.

Figure 98.—Colorado River and Navajo Mountain from the southeastern end of the Kaiparowits bench. Navajo Mountain rises 7,100 feet above the river.

Figure 99.—Hole in Rock.

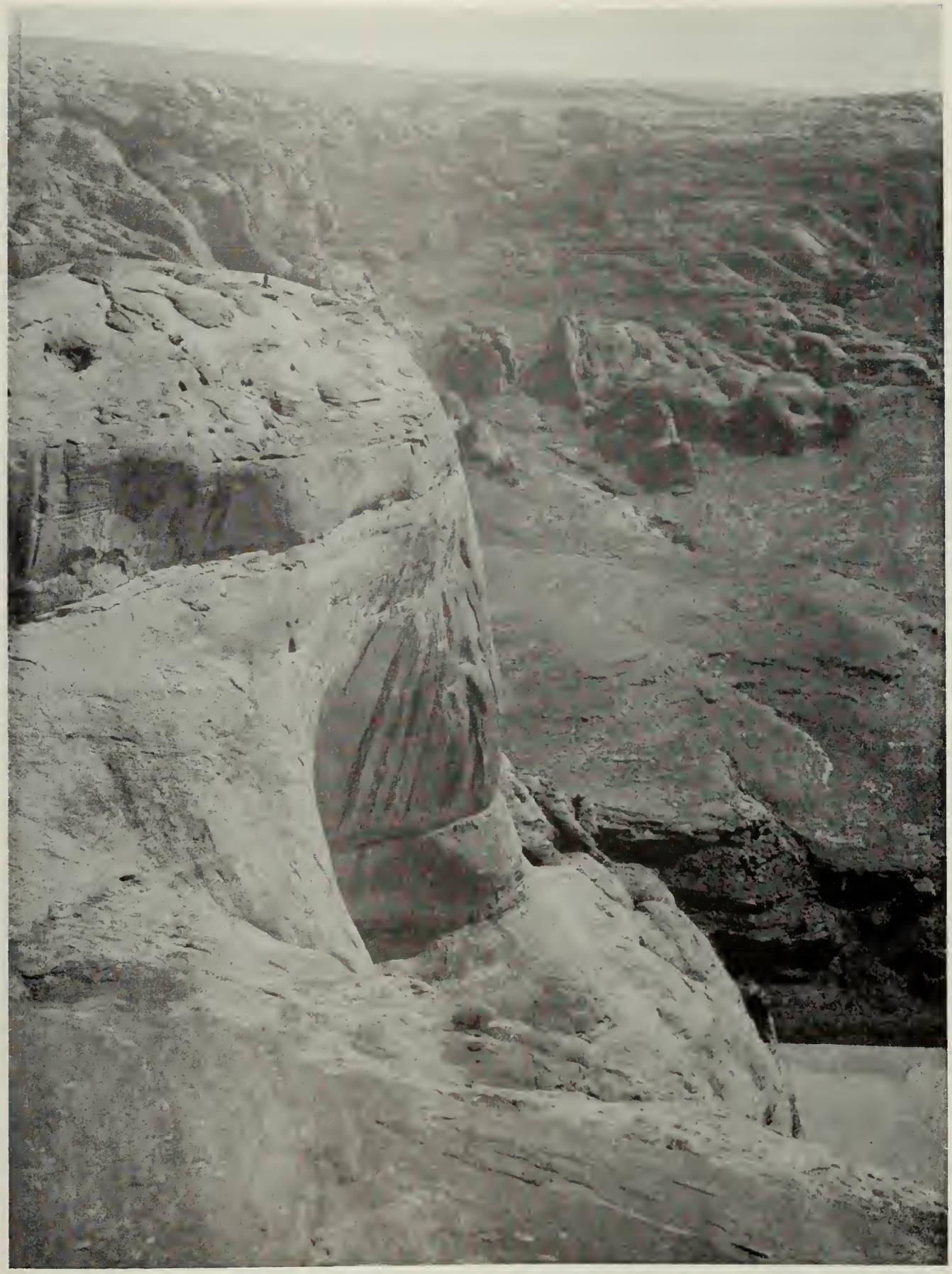

Figure 100.—View across Colorado River from left side of Hole in Rock. The point where the man is standing is about 1,400 feet above the river.

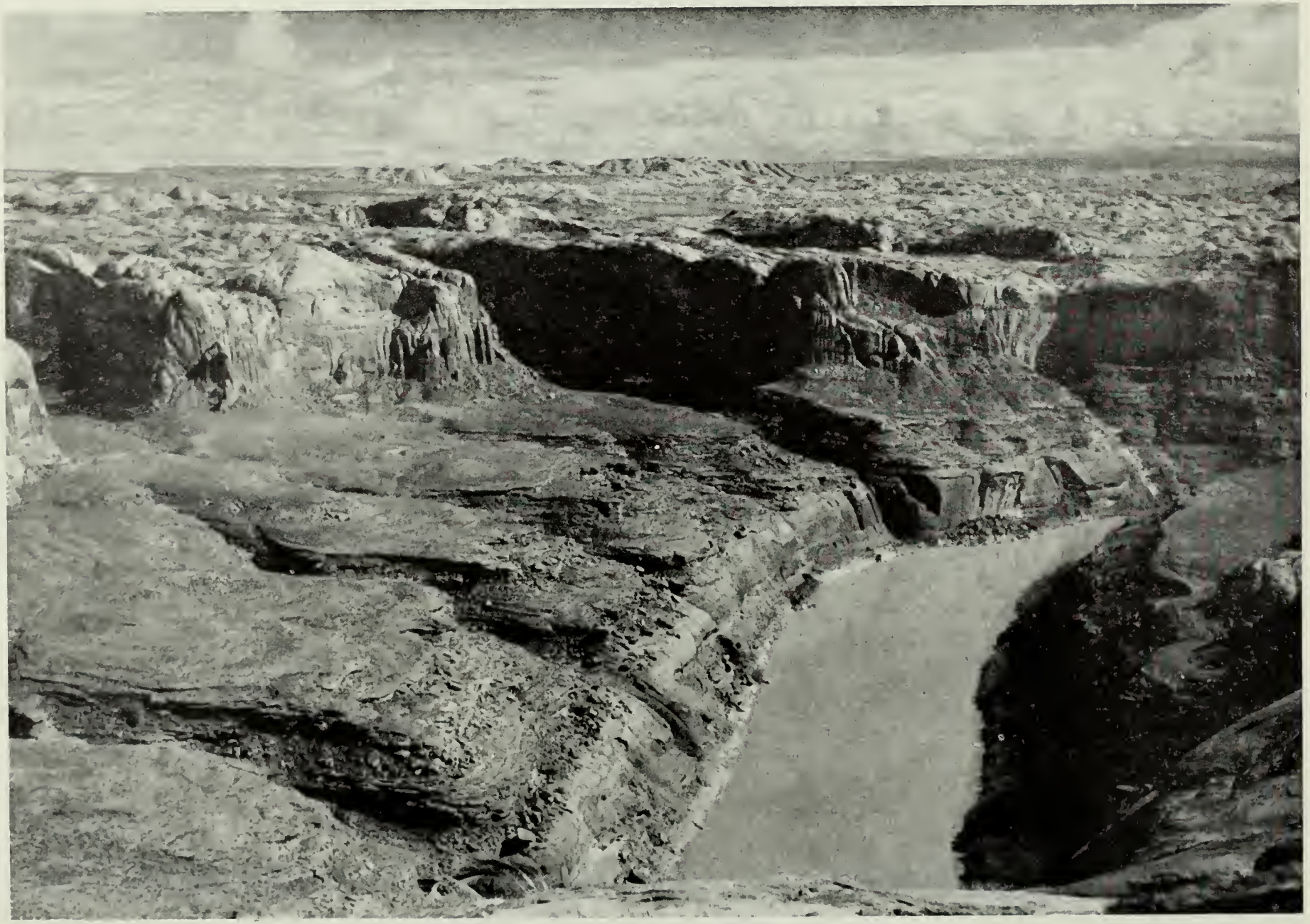

Figure 101.—The Colorado River Canyon at Hole in Rock.

Figure 102.—The Crossing of the Fathers. Escalante crossed the Colorado at this point in 1776. *(Air photo)*

Figure 103.—The Escalante River Canyon in Hole in Rock area. (*Air photo*)

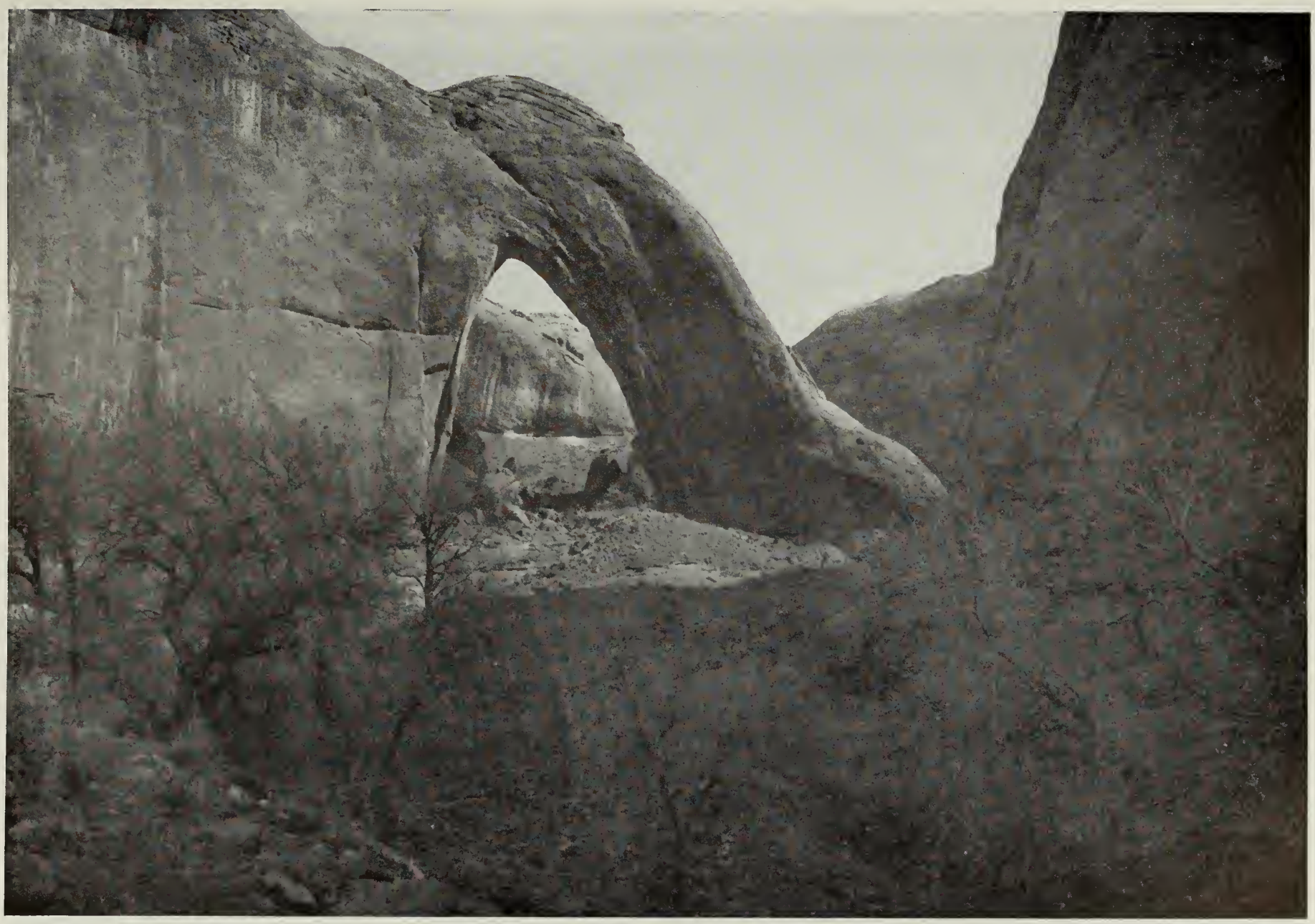

Figure 104.—Arch in Willow Creek Canyon in Hole in Rock area.

Figure 105.—Arch in Coyote Canyon in Hole in Rock Area.

miles long and very irregularly shaped. Five miles northeast of Warm Creek would be the wide water at the Crossing of the Fathers averaging about 2 miles wide and 3 miles long. A long, narrow promontory and a bend in the Colorado River would separate this wide water from the Last Chance wide water which would be about 1.5 by 1.5 miles at the Colorado and extend 7 miles up Last Chance Creek. Opposite Last Chance is West Canyon. The water would back up this canyon more than 6 miles and be only 300 or 400 feet wide. The mouth of Navajo Creek is 2.5 miles south of Warm Creek. At high water it would be possible to boat up this deep narrow canyon for 14 miles. In the canyon of the Colorado River the lake will average between 1,000 and 1,500 feet wide from the dam to Last Chance wide water. The mouth of Wahweap Creek and the mouth of Warm Creek are about 12.5 and 23.5 miles, respectively, upstream from the dam site. The Crossing of the Fathers wide water would be between 34.5 and 38.5 miles above the site. Last Chance is between 45.5 and 47.5 miles above the site. West Canyon and Navajo Creek are 41.5 and 21 miles, respectively, above the site and Aztec Creek is 65 miles above it. The high water would extend up Aztec and Bridge Canyons about 3 miles to within 1 mile of Rainbow Bridge.

With a boat making about 20 miles per hour it would be possible to make a pleasant 1-day trip from the dam to Rainbow Bridge and return, spending about 3 hours in the vicinity of the bridge. This trip would be about the same length as the boat trip on Lake Mead from Boulder Beach up into Grand Canyon.

Wahweap and Warm Creeks provide the first two places above the dam where there will be a comparatively gradual slope to the shore of the reservoir. With the feasibility of constructing a road from Kanab to the shore on the reservoir and the variety and interest of this section it appears to be a logical and desirable place for recreational boating and housing facilities, and for headquarters for boating operations and parties wishing to explore this section of Glen Canyon by land or water.

Goosenecks of the San Juan River, located 9 miles from Mexican Hat, have impressed all who have seen them. They are possibly the finest example of entrenched meanders in the country, interesting to geologists and certainly spectacular to the layman.

Arch Canyon.—This is a distinctive and outstanding feature to be seen by all visitors on their way to the Natural Bridges at the observation point on Elk Ridge not far from the Kigalia Ranger Station. Arch Canyon, approximately 15 miles west of Blanding at the head of Comb Wash and extending into La Sal National Forest, is a chasm of superb beauty with an unusual variety of color and a multitude of interesting towers and pinnacles. Because of its inaccessibility it is little known, but is one of the scenic jewels of the entire area. The upper and most scenic end of the canyon lies within the boundaries of La Sal National Forest. The Forest Service is cognizant of its recreational and scenic value and has planned for a camp and picnic area near the observation point and a trail leading into the canyon.

Fisher Towers are approximately 24 miles by the river road from the bridge crossing of the Colorado at Moab and directly north of the La Sal Mountains. From a distance, this detached and majestic group of pinnacles and spires rising 800 to 1,500 feet suggests a great architectural skyline of huge towers with elaborately sculptured facades. Some have dominant, unbroken vertical lines of the modern skyscraper, while others resemble great Gothic cathedrals with their wealth of delicate natural carvings. The towers of light red sandstone rise from a great base of elaborately sculptured, deep red or maroon mudstone. They are eminently different and distinct in a region where such erosional land forms are abundant.

LANDS, OWNERSHIP, LOCATION, AND AMOUNTS

The major portion of the Canyon Lands of southeastern Utah is unsurveyed public domain, (Pl. 7 in pocket). Private lands are concentrated in the irrigated and coal mining districts around Price, Utah, along the highways in Castle Valley, and at Green River, Moab, Blanding and Monticello. The preponderance of private land, shown on Plate 7 (in pocket), is outside of the circumferential roads previously described. Sections 2, 16,

32, and 36 of the surveyed lands in each township are State school lands. The State has a definite program for the consolidation of State lands through exchange for public domain, but so far as is known there has been no consolidation in this section of the State.

There are four national monuments within the area: Navajo National Monument in the Navajo Indian Reservation, consisting of three detached units totaling 360 gross acres; Natural Bridges National Monument, containing 2,650 gross acres, located near the head of White Canyon about 30 miles west of Blanding, Utah; Capitol Reef National Monument, 36,393 gross acres of rugged colorful scenery located east of Torrey, Utah; and Rainbow Bridge National Monument, 160 gross acres, west of Navajo Mountain, set aside to preserve the famous bridge. Bryce Canyon National Park, with 36,010 gross acres, is within the circumferential roads but at the edge of the high plateaus which form the topographic boundary of the west side of the area. The 34,250 gross acres in Arches National Monument north of Moab are just outside of the road belt. The 109,823 acres in the national park and monuments represent less than 0.9 percent of the total acreage.

The Abajo Mountain-Elk Ridge section of the La Sal National Forest, containing more than two-thirds of the total 516,768 acres (gross) in the forest, lies within the area and the La Sal Mountains section adjoins the area just east of Moab. The Manti, Fish Lake, and Dixie National Forests lie along the west edge.

All of the area south of the San Juan River and east of the Colorado River, about one-fifth of the 20,000 square miles, is part of the western and northern Navajo Indian Reservations.

All of the public domain land is included in grazing districts administered by the Bureau of Land Management.

Certain lands along the Colorado, Green, and San Juan Rivers have been withdrawn for Bureau of Reclamation water control projects. Other small scattered withdrawals have been made in connection with irrigation projects, chiefly in the section around Price, Utah. The large withdrawal on the Colorado River north of the La Sal Mountains is for the proposed Dewey Reservoir which is outside of the area under consideration.

USE OF NATURAL RESOURCES

Water.—Of primary concern to the State and the Nation is the proper utilization of the natural resources of this vast area in southeastern Utah. The Colorado, Green, and San Juan Rivers offer opportunities for great power developments. In the comprehensive plan for the development of the water resources of the Colorado River Basin consideration is given by the Bureau of Reclamation to the possibility of constructing two large hydroelectric dams on the Colorado River; one, either at the Glen Canyon site 4 miles above Lees Ferry, Ariz., or at an alternate site 15 miles above Lees Ferry, and the other at the Dark Canyon site in Cataract Canyon, 3 miles above the mouth of Dark Canyon. These two dams would impound the Colorado River from just above Lees Ferry to Moab, Utah, a distance of 279 miles, and the lower 62 miles of the Green River. Tentative plans for the Glen Canyon site indicate that a dam 414 feet high would create a reservoir which at normal water surface elevation of 3,528 feet would have a surface area of 65,000 acres and a capacity of 8,600,000 acre-feet. The slack water would extend 186 miles up the Colorado to the Dark Canyon Dam site. There conditions are reported favorable for construction of a high dam which would back water to Moab and up the Green River.

The Glen Canyon site would be accessible from United States Highway 89, 131 miles by road north of Flagstaff, Ariz. The Dark Canyon site is at present inaccessible except by boat or horseback. The nearest automobile trail is at North Wash, 18 miles downstream.

There are three power site possibilities in the San Juan River Canyon below Mexican Hat—one in the Goosenecks of the San Juan, one near the mouth of Slickhorn Canyon, and the other in the Great Bend of the river.

The potential dams and reservoirs would eliminate the thrills of boating down the untamed rivers. The depths of the river canyons would be reduced. The deadly rapids of Cataract Canyon, responsible for the tragic ending of several canyon voyages, and the sand bars and the often shallow waters of Glen Canyon, would be gone. But the Glen Canyon Reservoir would provide access to the wonders of the canyons.

The three dams on the San Juan River would have little potential recreational value and, as previously stated, would eliminate the thrills of boating down the twisting canyoned river to the Colorado. This trip has been popular in recent years under the guidance of Norman D. Nevills of Mexican Hat.

If it is eventually determined to be in the best interest of the people of the Nation to construct these large dams, the present wilderness character of the side canyons and the adjoining country can still be preserved, though the mighty rivers responsible for this wilderness will have become millponds. The dams would be lost in the canyons and have little or no effect on the surrounding scenery. On the other hand, the construction camps and roads, and the transmission lines could be objectionable features, destroying the present wilderness character of limited areas if not planned and constructed in the least conspicuous locations. For instance, transmission lines located where they are silhouetted against the sky are considerably more conspicuous than when they have a background.

Other resources.—The area is large enough and varied enough to permit the continued use and development of its resources. The unusual, colorful scenery and spectacular geological features, the canyoned rivers, the wealth of archeological material, and the great open, undeveloped spaces are considered by many people as recreational resources of the highest order which, under proper management, can become major economic assets to the State and Nation. The area is used extensively for grazing cattle and sheep and this use should continue under sustained-yield management. While no extensive mineral resources have yet been discovered and there is little indication that they will be, it remains a potentiality. Oil, magnesium salt, vanadium, soft coal, and some gold have been found. The limited forest areas are important for watershed protection, recreation, and grazing, but unimportant for timber production.

Except in certain limited sections where a single use is essential to obtain the greatest benefits, these resources can be developed and used simultaneously. The need is for each interest to understand, appreciate, and recognize the multiple values of the area. The vast unfenced range with its wandering herds and cowboys and sheepherder camps have a definite appeal to the recreational visitor. The old cow camp may be developed into a camp for vacationists wishing to ride the trails, see the canyons, and visit archeological features. A new development for the accommodation of tourists may double as a headquarters for cowboys and miners. The range will not give full recreational value or the best beef and wool without limiting grazing to a conservative sustained-yield basis, which assures a good ground cover and checks erosion. Roads can be constructed to serve recreational travel and provide access to the range and mines.

Elk Ridge in the La Sal National Forest has been an important summer grazing area but it is showing signs of overuse. As the area becomes better known it is certain to be one of the major recreation centers in the Canyon Lands. It is believed to be a suitable location for lodges, camps, and possibly a landing field serving people visiting Natural Bridges, Arch Canyon, Dark Canyon, Beef Basin, Fable Valley, Gypsum Canyon, and other places of interest in the surrounding canyon lands. Eventually the recreational use of Elk Ridge may be of primary consideration, with grazing a secondary use.

Grays Pasture and Lands End are other sections of major recreational value, where grazing and other uses should be subordinate to that major value. The other centers of recreational importance—Navajo Mountain, Rainbow Bridge, Monument Valley, Hole in Rock, Escalante River Canyons, and The Needles—have little value except for recreation.

Administration.—In the administration of the national forests, the Forest Service recognizes recreation as one of the important uses of forests, along with timber production, grazing, watershed protection, and wildlife production. Areas where public recreation interests are concentrated are dedicated exclusively for recreational use to protect the area and the public.

A function of the Bureau of Land Management is to plan, manage, and execute a broad conservation program for the development, protection, and restoration of the soil, water, and forage resources on the Federal range, and to regulate the grazing therein, so that the dependent livestock industry

may be stabilized around a profitable, orderly use of all the resources involved.

The administration of the Federal range involves many of the same problems as the administration of the national forests. For both there are economic and nonvendible values to be considered.

This is the case in the Canyon Lands of southeastern Utah. Much of the land is primarily useful for grazing, yet it has intrinsic recreational values which should be preserved under Bureau of Land Management and Forest Service administration.

In some sections the recreational values are of sufficient importance to equal or exceed the grazing or timber values.

The two areas in the Canyon Lands of Utah outlined on Plate 9 (in pocket) contain the most outstanding scenic and recreational features not included in the Indian reservations. In the administration of the lands within these two areas it is believed that recreation should be the major use, with grazing and other uses secondary. Certain sections of these areas which contain known scenic and scientific features of national significance should be given adequate protection. These sections are shown by cross hatching on the same map.

The National Park Service recommends that full public notice be given before determinations are made regarding proposals for establishing any areas for park and recreational purposes so that all interests can be heard and considered.

PRESERVATION OF EXISTING FEATURES

The Canyon Lands of southeastern Utah have scenic, scientific, and wilderness features which are of significance to the State and Nation. The recreational and economic benefits to be gained by preserving these features may be facilitated by following the policies outlined below:

1. Roads should be constructed only when amply justified, based on positive need. Where such construction is justified, it should be performed in a manner which will render it as inconspicuous as possible.

2. Since the airplane is supplementing other major forms of transportation throughout the world, it is reasonable to assume that it eventually will be used as a means of access to the remote

Figure 106.—The Henry Mountains from the road between Hanksville and Hite, Utah.

sections of the Canyon Lands, thereby greatly reducing the intrusion of surface transportation facilities into the scene.

3. Encourage business catering to recreational interests and tourist travel to locate in the vicinity of existing towns and certain recreational development centers, rather than at random throughout the area.

4. As the West develops, the roads which one may travel without having the feeling of being fenced in are gradually becoming fewer. Fences on both sides of the road and, to a lesser degree, pole lines, tend to separate the road from the adjoining country which creates the feeling that one is detached from it rather than being a part of it. This effect will be eliminated if only such fences are constructed as are absolutely necessary and if they are removed when their need no longer exists.

Roads.—The topography of the Canyon Lands has permitted limited travel east and west and has prohibited vehicular traffic north and south. The only east-west route which has been used to any extent in the past and has recently been improved, crosses the Colorado River at Hite. Surveys of the State Highway Department indicate that the only feasible route for an east-west highway across the Colorado River between Green River, Utah, and Lees Ferry, generally follows this old location. The route suggested by the highway survey is shown on Plate 9 (in pocket). To preserve the essential character of the area, it is questionable whether any other through highway should be constructed. Only spur roads providing access to the major centers of recreational interest are recommended. In all cases these proposed spur roads would generally follow existing truck trails and serve the grazing and mining interests as well as recreation. The spur roads should be of limited width and of a standard permitting year-round travel.

Fortunately, all of the major centers of recreational interest shown on Plate 9 (in pocket) are now accessible by automobile over trails which in most cases are very poor. It would be feasible to build good all-weather roads from the outer belt of highways to each of the suggested development sites. At these sites, or in the immediate vicinity, there is ground suitable for a landing field for small planes. While it is not absolutely essential to have a road to every landing field, such a road is considered desirable for use in hauling in equipment, building materials, and many supplies.

Air travel and landing fields.—It is believed that much of the tourist travel through the Canyon Lands will be by air because of the great distances and the necessarily circuitous routes that must be followed on land.

At the present time, one major commercial air line crosses the area on the route between Grand Junction, Colo., and Las Vegas, Nev. This line has an auxiliary landing field near Hanksville, Utah. A feeder line has been authorized to connect Grand Junction, Price, Provo, and Salt Lake City. To the south Winslow, Ariz., is the nearest point on a major air line. It appears that Grand Junction, Price, and Winslow would be the logical starting points for air tours over the Canyon Lands. At the present time there are landing fields in the area at Hanksville, at Goulding's Trading Post in Monument Valley, on the southeast side of Navajo Mountain, at Bryce Canyon, and at Fredonia, Ariz. For the safety and convenience of air travel, possible landing field locations convenient to all the major recreational centers and at certain intervening spots have been shown on Plate 9 (in pocket). If this plan were followed, at no time would a plane be more than 25 miles from a landing field.

Recreational facilities.—As has been stated, practically all of the population of the region lives in towns and limited irrigated districts. There are only a few isolated ranches. Men running cattle on the range have their homes in the towns where schools, stores, churches, and social activities are available. This practical custom has resulted in the concentration of such developments at favorable points and a corresponding complete freedom of great areas of open country from any interruption by scattered reminders of town life. It is impossible to find such a set-up in most sections of the United States where the people live on the land they graze or farm. Future developments, including major facilities and businesses catering to the recreational interests and tourist travel, should follow this pattern of land use. However, the Canyon Lands are so extensive that it would be impracticable to confine all such facilities entirely within

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Figure 107.—Mouth of Trachyte Canyon from site of former settlement of Hite.

Figure 108.—Trachyte Canyon joins the Colorado River at Hite. *(Air photo)*

the bordering towns. Hence on Plate 9 (in pocket) the recreational centers have been shown located considerable distances from the towns at points where the cattlemen and the visitors would most likely wish to make their headquarters while working or exploring the various sections of the Canyon Lands.

The development of the recreational centers might well be in the ranch style, offering meals and lodging, camping supplies, pack and saddle animals, guides, gasoline and oil, and the like. The suggested landing fields indicated on the map are convenient to the development areas so that they might serve both airplane and automobile travel. From these centers horseback trails might lead to the various points of interest.

The Elk Ridge center at an elevation of 8,500 feet might be primarily a summer-use area because of the heavy winter snows; the Grays Pasture-Junction Butte and the Lands End centers would have longer periods of use and the facilities and services could be provided on a year-round basis. The Needles, Hite, Hole in Rock, and Wahweap centers appear to be suitable for year-round use. Hite, with an average annual temperature of 59.7 degrees, seems to be an ideal site for a winter resort on the river and might become one of the two main centers for boating and fishing on the Glen Canyon Reservoir the year around. The other center might be on the wide water somewhere between Wahweap Creek and Last Chance Creek.

Above Hite the recreational use of the Green and Colorado Rivers, or the reservoir to be formed by the proposed Dark Canyon Dam, would logically center at Moab and at or near Green River, Utah. Moab, with its scenic setting on the Colorado River and conveniently located to the many points of interest, seems destined to become an important recreational and tourist center.

Only the Hite and Wahweap centers would be largely controlled in their development by the potential Glen Canyon and Dark Canyon Reservoirs. The importance of Hite might be materially increased by the creation of the Glen Canyon Reservoir. The development at the Wahweap site would depend almost entirely on the creation of the reservoir. There is little need for a recreational center at that point if the reservoir is not created. However, there might be a small camp on Warm Spring or Wahweap Creeks to serve the cattlemen and the

Figure 109.—Arch Canyon from Elk Ridge.

few who would wish to visit this remote section. If the Glen Canyon Reservoir is not created, the main boating and recreational center serving the lower end of Glen Canyon would probably be at Lees Ferry.

The Needles, Lands End, Elk Ridge, and Hole in Rock can be important centers for pack trips through the fascinating country surrounding them. Lands End sometimes has heavy snows in the winter, but pack trips can be made from there the year round as there is seldom snow in the Standing Rocks Basin around the junction of the Green and Colorado Rivers.

The Grays Pasture-Junction Butte area is certain to be visited by many tourists traveling by plane and automobile because of its convenient location in relation to main arteries of travel, the interesting features of the area, and the outstanding view of the Canyon Lands.

The big flat south of the Knoll appears to be suitable for the development of a landing field and there are many good sites for a lodge and other recreational facilities. A possible lodge site indicated on Plate 10 (in pocket) is the fairly level land lying west of Muffin Butte and south of Aztec Butte near the Y in the roads to Junction Butte and Upheaval Dome.

Consideration should be given to constructing a shorter road from Moab to the Knoll by way of Sevenmile Canyon. This route would be considerably more scenic than the present road and eliminate about 24 miles of unnecessary travel, making the distance from Moab to the Knoll only 20 miles.

Of special importance in the development of this area would be the construction of well-defined trails around and into Upheaval Dome so that people may see this fascinating and almost unknown geologic wonder.

CHAPTER IX

Dinosaur National Monument

Dinosaur National Monument was originally established as an 80-acre area by proclamation of President Wilson on October 4, 1915, under authority of the Antiquities Act, for the purpose of preserving a rich deposit of fossilized dinosaur bones found here in an excellent state of preservation. By proclamation of July 14, 1938, signed by President Franklin D. Roosevelt, the area was extended to include other resources of great scientific interest, such as the canyon of the Yampa River and the Canyon of Lodore, Whirlpool Canyon, and Split Mountain Canyon on the Green River. The total area, including State and private lands within the exterior boundaries, as of October 1945, is approximately 209,744 acres.

LOCATION

The monument lies in semiarid northwestern Colorado and northeastern Utah; about 70 percent falls within Colorado and 30 percent in Utah. It is essentially a canyon-plateau area. Earth processes of a past geological age with contemporaneous biological developments of a spectacular nature have produced its outstanding features. It lies on the southern flanks of the eastern end of the great east-west Uinta Mountain uplift. While there are other notable geological, wilderness, and scenic values in the vicinity, the monument is, from the standpoint of such values, the spectacular core of a considerable region on the Upper Colorado River Basin. Between the northern end of the monument and the Utah-Wyoming State line are noteworthy canyons on the Green River, such as Red Canyon and Flaming Gorge. Fine as they are, they do not possess such exceptional qualities as are present in the monument.

SCIENTIFIC, SCENIC, AND RELATED VALUES OF THE MONUMENT

Functionally, the monument consists of two contiguous units which will be referred to as the Quarry Unit and the Canyon Unit. The comparatively small Quarry Unit, comprising three or four thousand acres, includes not only the 80 acres of the original national monument, but also surrounding land west and north of the Green River and south of Split Mountain. The Canyon Unit, consisting of about 206,000 acres, comprises the rest of the monument. Operationally, the monument is split into three distinct units of roughly equal size by the virtually impassable canyons of the Green and Yampa Rivers.

Quarry Unit.—The most remarkable single feature of the monument is the world-famous dinosaur fossil deposit in the Quarry Unit. The fossils are found in the Morrison formation (upper Jurassic) on the south limb of the Split Mountain anticline. This formation underlies the shales and sandstones of the Cretaceous, and is underlain by other strata of the Jurassic. Below the Jurassic lie the "red beds" of the Triassic group. In the vicinity of the "Quarry," the strata of the Cretaceous, Jurassic, and Triassic dip sharply to the south. Extensive excavations have been carried out, and considerable removals of important fossils have been made. It is to be expected that the unexcavated parts of the formation at the "Quarry" are just as rich in quality and variety of fossil specimens as was the excavated part.

Near the "Quarry" the upturned sedimentary rock formations tell a geological story of events preceding and following the era when dinosaurs roamed over a landscape much different from that of the present. The tilted rocks exposed in the Quarry Unit are part of the thousands of feet of

Figure 110.—Dinosaur Quarry—Dinosaur National Monument.

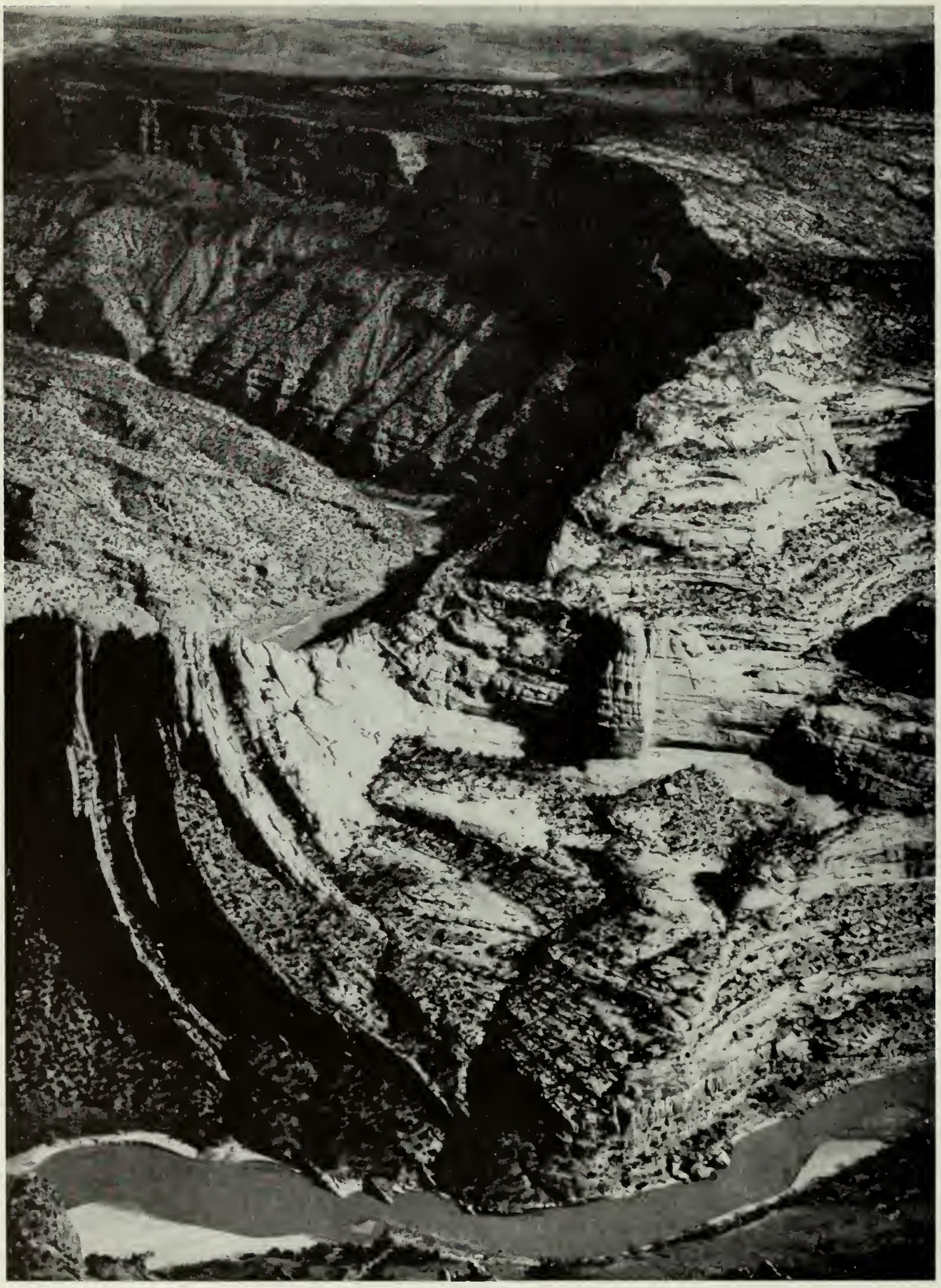

Figure 111.—Green River Canyon from Harpers Corner in Dinosaur National Monument. The river is 2,400 feet below observer.

strata that have been raised in an anticlinal fold parallel to and south of the main east-west trending Uinta Mountain uplift. The view from the hills above the fossil bed is worthy of recognition. There, in the presence of the evidence of the most spectacular biological development of the past, one may contemplate the future.

Because of its paleontological values, the Quarry Unit justifies its inclusion in the National Park System.

Canyon Unit.—Geological and scenic values are of predominant importance in the Canyon Unit. Here the folded and faulted sedimentary rock formations have been cut by the deeply intrenched meanders of the Green and Yampa Rivers. The dynamic process of river erosion has produced a colorful, rugged wilderness of deep canyons, dissected erosional benches, and bold promontories.

The precipitous Canyon of Lodore on the Green River, which is upwards of 2,700 feet deep near Triplet Falls, has been cut in quartzites, sandstones, limestones, and shales, some of them characterized by deep reds and purples. It possesses an exceptional degree of grandeur. The Yampa River Canyon, whose course is marked by deeply intrenched meanders, here and there separated by narrow promontories, has been cut in sandstones and limestones. Its walls are often sheer and, in the vicinity of Warm Springs Draw, rise about 2,000 feet above the Yampa. One of the more notable parts of Whirlpool Canyon is the section downstream from Sage Creek, where the river has cut through the side of an abrupt mountain fold, leaving a relatively thin outer shell or crust of fold standing as the north wall of the canyon. The Split Mountain Canyon is of interest for the way in which the river has cut along the middle of the fold, about on its axis. All of the canyons possess notable scenic qualities.

Jones Hole, Echo Park, and Castle Park are three of the more noteworthy, relatively small areas of the monument. Jones Hole and Echo Park contain perennial clear streams. The three areas are walled by high cliffs. In Echo Park at the junction of the Green and Yampa Rivers, and in Castle Park at the junction of Hell Creek and the Yampa, the cliffs are of Weber sandstone. In Jones Hole, they are of limestones and sandstones along Ely and Jones Hole Creeks. In each case, a feature unusual in this region is the relative abundance of deciduous cover.

In addition to the predominant geological, scenic, and wilderness values of the Canyon Unit, there are distinct though relatively minor biological interests. Deer are numerous in most sections; mountain sheep are present, though rarely seen. The vegetative cover embraces a variety of plant habitats, in life zones ranging from Upper Sonoran (mixed desert shrub and juniper-piñon) through Transition into Boreal (aspen, lodgepole, and fir). There are many plant associations correlated with geological structure, and many interesting biotic units whose origins are related to the development of the canyons and the local mountain structures on the flank of the Uinta Mountains.

Varied and frequent evidences of primitive Indian occupation constitute the archeological exhibit. Evidences of prehistoric Indian life are found in many sectors—in highlands, on benches between highlands and canyons, in canyons, and in valley bottom "parks" such as Castle Park, Hardings Hole, Pool Canyon, Echo Park and Island Park. They include petroglyphs, camp sites, rock shelters, middens, and caves that were inhabited or used for storage.

Variety in the characteristics of the Canyon Unit is a quality of exceptional importance. Geological exhibits of sedimentation, and stratigraphic, structural, and physiographic features are of prime significance. Second only to them are the conspicuous aspect of wildness and the scenic values which so often form an inseparable combination with those of geology. The Canyon Unit is of national importance for its geological and wilderness values. It is notable and distinctive, and in its present, unaltered state, warrants its existence in the National Park System.

RECREATIONAL VALUES OF THE MONUMENT

To date, the monument has received a minimum of planned development. Access to the Quarry Unit is provided, but no provision for public access into the Canyon Unit has been supplied. Such access to the latter as exists is by way of low-standard roads which are used by ranchers in the locality. Recreational utilization of the monument, save for the

part centering around the quarry, is negligible at present.

Recreational values exist, though they are undeveloped. The area offers excellent possibilities for the layman to see and learn interesting stories of the land forms and the plant and animal life of past geological periods, the early occupation by man, and the present plant and animal life. Over most of the monument the geological features—the thick sequence of rock formations of Paleozoic and Mesozoic ages, the structural folds and faults, and the rugged relief—blend with the scenic features and the wilderness characteristics to form a setting which offers many opportunities for education, spiritual uplift, and physical recreation, including camping, boating, horseback riding, hiking, and fishing.

PROPOSALS BY THE BUREAU OF RECLAMATION

Potentialities for using the water resources of the Green and Yampa Rivers within and near the national monument are being studied by the Bureau of Reclamation. Under consideration are proposals for the Echo Park and Split Mountain Dams, reservoirs, and appurtenant facilities.

Echo Park Dam and Reservoir.—The proposed site of the Echo Park Dam is in the narrow inner gorge of the Green River at a point near the base of the tip of Harpers Corner. Normal stream elevation at this point is about 5,048 feet. At high water, currently being considered for elevation 5,550 feet, the reservoir would run throughout the length of the Green River Canyon within the national monument upstream from the dam, and would extend northwestward from the north boundary, through Browns Park, for a distance of 30 miles or more by river. Another arm of the reservoir would lie in the Yampa River Canyon, and would extend to a point in Lily Park east of the eastern boundary of the monument.

Maximum drawdown might amount to 150 feet during periods of extreme drought. High-water levels could be expected to take place normally during July and August, with relatively high levels in September. Low water ordinarily would occur during the late winter months before spring runoff. Seasonal variation would be from 20 to 50 feet.

The Bureau of Reclamation has not made a decision on the height of the dam, location of construction roads, construction camps, or power lines. It is planned to open a gravel pit in Island Park.

Split Mountain Dam and Reservoir.—The proposed site of the Split Mountain Dam lies near the head of Split Mountain Canyon. A dam 118 feet high to raise the water surface to an elevation of 5,048 feet is being considered. A reservoir at that elevation would inundate Little, Rainbow, and Island Parks, and the bench land at the mouth of Jones Hole. Present studies indicate practically no fluctuation either seasonally or annually. Only in years of extreme drought would there be any radical lowering of water level.

The Bureau's report of March 1946, on the Colorado River Basin states: "A power head of 200 feet could be utilized by means of a pressure tunnel in three sections, extending from the dam 8.3 miles downstream to a power plant 5 miles up the river from Jensen, Utah."

EFFECTS OF PROPOSED DAMS, RESERVOIRS, AND RELATED STRUCTURES UPON NATIONAL MONUMENT VALUES

Echo Park Dam and Reservoir.—Information to date indicates that the Echo Park Dam, reservoir, and appurtenant structures and facilities would not affect the Quarry Unit of the monument. They would, however, seriously and adversely affect the Canyon Unit. The dam would be totally alien to the geology and landscape of the monument. It would be seen from the upper end of Whirlpool Canyon and from points along the rims of the canyon, and, from the viewpoint of monument values, would be a lamentable intrusion.

Power lines would have a widely damaging effect upon wilderness and scenic values. Development of a power project would require the introduction of construction and operation roads and other facilities which would otherwise not be built. They could hardly be constructed without injury to geological and scenic values of the Canyon Unit.

Far-reaching effects upon scenic, geological, and wilderness values would result from impoundment of the Echo Park Reservoir. The two-arm artificial lake would cover wholly or in part a number of

Figure 112.—Steamboat Rock, Echo Park, and the Green River.

fine geological exposures, would reduce the visible height of canyon walls, and would substitute long bodies of still water, widening here and there into bays, for the characteristic rivers and fringing vegetation which now lie in canyon bottoms. The Canyon of Lodore would contain a narrow fiord-like lake which would inundate a portion of the exposed geological formations in the canyon bottoms. The same is true of the Yampa Canyon.

Particularly deplorable effects of the Echo Park Reservoir upon geological and wilderness features would occur in the localities of Pats Hole and Echo Park near the junction of the Green and Yampa Rivers and in Castle Park and Hardings Hole on the Yampa River. A large part of Pats Hole would be covered by the Echo Park Reservoir. The fine spring and Pats Cave where the interesting character, Pat Lynch, lived alone for many years, would be submerged. Even more unfortunate, would be the submersion of the floor of Echo Park, the great reduction in the visible height of the nearly vertical sandstone walls of Echo Park which rise several hundred feet above the floor, the inundation of about one-half of Steamboat Rock, and partial obliteration of noteworthy folds and faults so strikingly revealed in this area.

Split Mountain Dam and Reservoir.—A dam at the head of Split Mountain Canyon would detract materially from the geological and wilderness values of the entrance to the canyon. Construction operations would unavoidably cause some permanent scarring in the locality of the dam site.

From the viewpoint of natural values, the Split Mountain Reservoir would adversely affect Little, Rainbow, and Island Parks. The cluster of islands in the river and the pleasant bottoms of brush, grasses, and fringing cottonwoods would be replaced by a large lake of three bays. The rushing river with its rapids and whirlpools in Whirlpool Canyon above Island Park would be replaced by a long, narrow body of still water.

Figure 113.—Whirlpool Canyon—spurs of Wild Mountain at left; Zenobia Peak is the high point on skyline (right); and Echo Park Dam site is in the narrow inner gorge.

At the time this report was prepared, data were not available to the National Park Service from which to determine whether construction of a pressure tunnel from the Split Mountain Dam to a power plant 5 miles upstream from Jensen would affect the Quarry Unit.

Concerning transmission lines, comments relating to the Echo Park project apply generally to the Split Mountain proposal.

Other effects.—Submersion of parks and the bottoms and slopes of canyons and entering draws undoubtedly would affect adversely the existing biota of the area. A number of interesting archeological sites would be submerged, particularly in the vicinity of Echo Park, Castle Rock, and Hardings Hole along the Yampa River.

Summary.—Construction of the Echo Park and Split Mountain Dams, reservoirs, and related temporary and permanent facilities would materially and deplorably alter the dominant geological and wilderness qualities and the relatively minor archeological and wildlife values of the Canyon Unit of Dinosaur National Monument. Its present scenic and scientific values and its wilderness character would be seriously altered. On the other hand, creation of the proposed Echo Park and Split Mountain Reservoirs would undoubtedly produce other recreational opportunities.

POLICY AND PLAN FOR THE NATIONAL MONUMENT

In accordance with the Congressional Act of 1916 creating the National Park Service, it has been and is the responsibility of the Service to conserve the scenery and the natural and historic objects and wildlife within the areas in the National Park System, and to provide for the enjoyment of them in such manner and by such means as will leave them unimpaired for future generations. Accordingly, the major aims of the National Park Service in its administration of the Dinosaur National Monument are:

1. Protection of unimpaired resources and, through elimination of factors that have modified other natural conditions, the restoration of those other conditions to their original state. The modifying factors principally involved are agricultural pursuits which consist largely of grazing, and the presence of non-Federal lands within the exterior boundaries of the area.

2. Protection and preservation of archeological features.

3. Provision of such facilities as are necessary to enable visitors to study and enjoy the features of paleontological, geological, wilderness, and related interests, and as are required for proper recreational use and administration of the area.

CONCLUSIONS

The policy of the National Park Service, as the administrative agency now primarily responsible for the national monument, has been, and is, to make the protection of the natural and archeologocal values of the area the controlling factors in administering it. The question of whether this policy is to be changed to permit water uses will require for its solution a review of all probable advantages and disadvantages arising from such use.

Dinosaur National Monument is eminently qualified, in the absence of very strong special reasons to the contrary, to justify its retention as a unit of the National Park System. Certain parts of it should be made reasonably accessible by road and accommodations provided for visitors just as soon as funds become available. Before authorization is given to develop its water resources and to recognize water use as the principal consideration in the administration of the Canyon Unit, it should be clearly shown (1) that economic and social values deriving from such development and use would largely and certainly exceed the economic costs of producing them; (2) that it would be more economical to develop the water resources of the monument rather than other resources available for the same purpose within practicable reach; and (3) that it would be of greater benefit to the whole Nation to develop the area for water storage and power than to retain it in a natural state for its geological, wilderness, and associated values for public enjoyment.

Figure 114.—Meanders of Yampa River near its junction with the Green River.

Figure 115.—Yampa River Canyon.

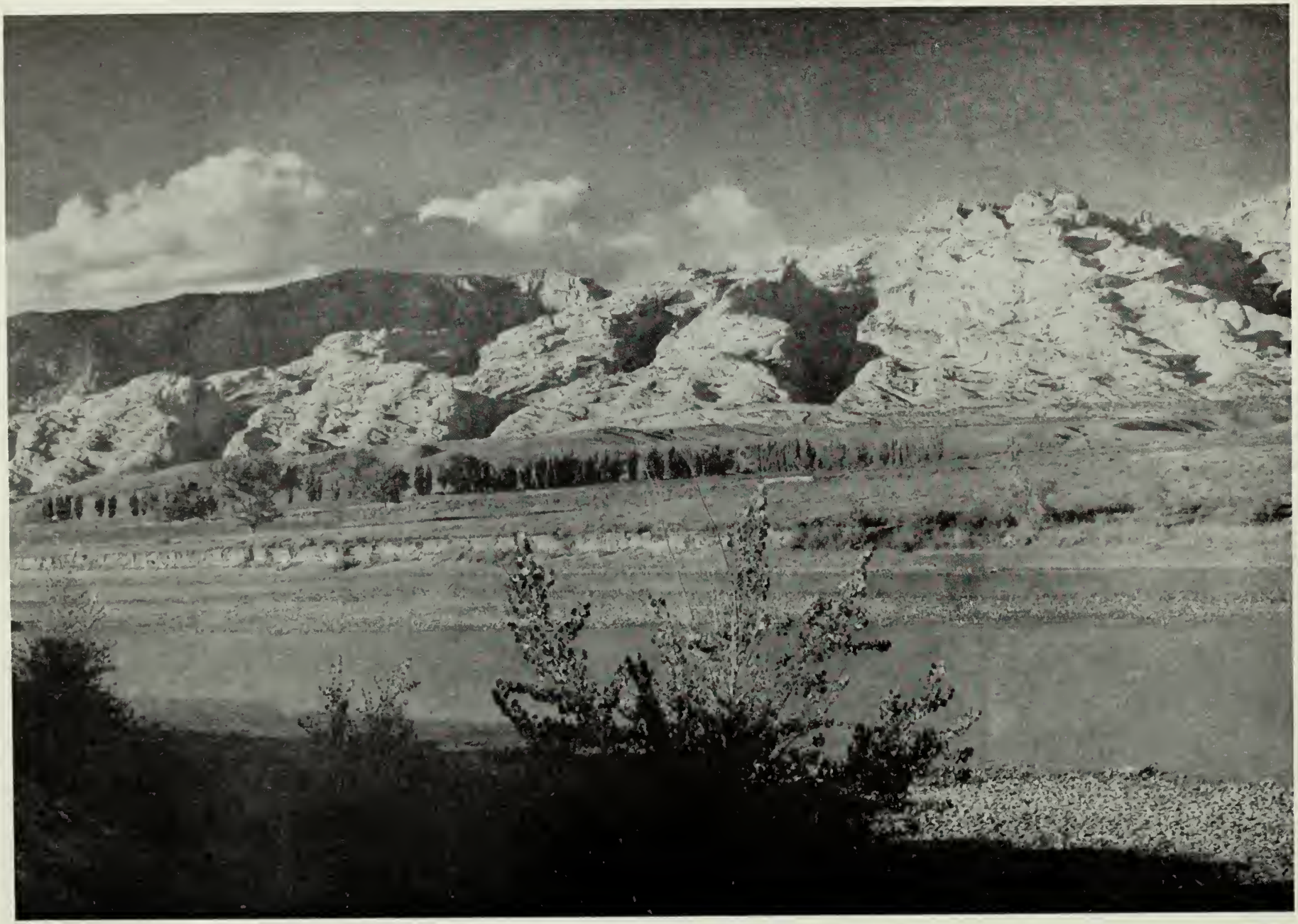

Figure 116.—Split Mountain from the banks of the Green River.

Conservation of Recreational Resources

The Colorado River Basin lies directly across all lines of travel between the rapidly increasing population of California and the densely populated eastern half of the United States. To a large extent in the past, it was considered just a vast space one had to cross on the way to California. Now, with the Pacific Coast more fully developed, people seeking undeveloped, uncrowded areas are beginning to discover the Colorado River Basin. The increased consciousness of color, brought about by colored photography, is causing people to become aware of the beauties of the region. Moving picture companies have discovered that the clear air, the high percentage of sunshine, and the great variety of colorful unspoiled scenery makes southern Utah and Arizona ideal for taking colored photographs of outdoor scenes. The same features are attracting more and more vacationists.

It is time for immediate action which will assure preservation of the many and varied recreational resources of the Colorado River Basin. It is also time to develop facilities which will enable people to see and enjoy the region. There are natural limitations on the amount of land that can be placed under cultivation. There is a limit, which has been reached in most sections, on the number of domestic animals that can be grazed. But the possibilities for the development of the recreational use of the basin are almost unlimited.

Much has been done. Vast areas, chiefly the higher plateaus and mountains, were designated as national forests in the early 1900's primarily for protection of the watersheds and for forage, timber, and wildlife production. Since their establishment, it has been found that many of them contain scientific and recreational features of national importance. A number of areas originally included in the forests have been set apart and dedicated as national monuments, while three other areas have been rededicated as national parks. These areas are now administered by the National Park Service. A number of other areas of major recreational value remain in the national forests. Some of these, in high remote sections of the forests, have been declared wilderness or primitive areas. Recreation is now recognized by the Forest Service as one of the important uses of the forests. In addition to the national parks and monuments originally included in the national forests, a number of other areas have been set aside as national parks and monuments to preserve their intrinsic qualities for the enjoyment, education, and inspiration of all people for all time.

The establishment of these national forests, national parks, and national monuments has been the most important factor in insuring the preservation of the recreational resources of the basin. So far, only California, Nevada, and Arizona have established State parks in the basin. Utah, however, has recently indicated interest in this direction. This is fortunate, as there are many areas which, while not qualified for establishment as areas within the National Park System, nevertheless merit preservation as State parks or monuments.

IMPORTANT RECREATIONAL AREAS AND SITES WHICH SHOULD BE PRESERVED AND DEVELOPED

In addition to the areas of high recreational value described in preceding chapters, there are certain areas within the Colorado River Basin which contain outstanding existing and potential recreational resources. Some are believed to be of national importance. Others are primarily important to the State or region in which they are located. It is not recommended that all of the areas be set aside exclusively for recreation but that the preservation and development of the recreational resources be at least one of the major elements in

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any future plans affecting them. Local, State, and Federal agencies should cooperate in planning for the use and development of these areas so that the people living in the basin and in other parts of the United States may enjoy the fullest benefits from them.

WYOMING

1. Wind River Range. The western slope of the Wind River Range is a mountain area of such exceptional scenic quality and recreational value as to be of national importance. A number of peaks in the range reach elevations of more than 13,000 feet. Gannett Peak, the highest in Wyoming, reaches 13,785 feet, topping the Grand Teton by 20 feet. The Forest Service has set aside a large portion of this region of picturesque peaks, ridges, more than 900 lakes, and the largest glaciers in the United States as a wilderness area accessible only by trails.

The main approach to the area is from the south over United States Highways 187 or 189. Highway 187 continues northwest to the Jackson Hole country. Low-standard roads lead from Highway 187 to the foot of the range, where several lakes are located at the mouths of ravines. With the improvement of access to the area it can become one of the major attractions of the Rocky Mountains for visitors from all parts of the United States. The recreational resources can become of major economic value to the nearby communities.

2. Fossil Quarries. Fossil Mountain west of Kemmerer, Wyo., and one of the quarries southwest of Granger, Wyo., should be preserved and developed as examples of the sites from which were obtained the famous fossil mammals, fish, birds, and plants exhibited in American and foreign museums.

3. Fort Bridger is the historic site of the famous trading post built by Jim Bridger in 1841 and served as a base of operations in the western fur trade, the Oregon Trail immigration, the Pony Express, and the Union Pacific Railroad. It was leased by the Federal Government as a military reservation in 1859 and abandoned in 1890.

COLORADO

1. The San Juan-San Miguel-Uncompahgre Mountain area in southwestern Colorado is one of the most extensive spectacular mountain regions of the United States. This area, at the headwaters of the Dolores, San Miguel, Animas, Los Pinos, Rio Grande, Lake Fork, and Uncompahgre Rivers, is one of jagged, steep mountain peaks; deep precipitous canyons; dashing streams; beautiful waterfalls; lakes set in austere backgrounds; extensive timberline areas and forests unmarred except by fire. For natural beauty of the grand and rugged mountain type, the area cannot be excelled. Numerous streams and lakes abound in trout. Deer, elk, mountain sheep, bear, beaver, grouse, and ptarmigan are all found in considerable numbers.

The area is bisected by United States Highway 550, a scenic mountain road connecting Durango, Silverton, Ouray, and Montrose, Colo. At Red Mountain Pass the highway reaches an elevation of 11,018 feet above sea level.

The Needle Mountains and the Grenadier Range, spectacular groups of mountain peaks, at least 18 of them more than 13,500 feet high, and three more than 14,000 feet high, are east of the highway between Durango and Silverton. The San Miguel Mountain section west of the highway varies in altitude from 9,500 feet to 14,250 feet at the top of Mount Wilson. The Uncompahgre section straddles the highway in the vicinity of Ouray. Uncompahgre Peak, 14,306 feet, Wetterhorn Peak, 14,020 feet, and Mount Sneffels, 14,143 feet above sea level, are the highest peaks, but several others in this section are more than 13,000 feet high.

The area is a mecca for geologists. Here the whole story of glaciation is easy to read and such features as the great rock streams and mud flows, not duplicated elsewhere in the United States, are fully displayed.

Extensive mining operations have been carried on in the region during the past 50 years and gold, silver, lead, and zinc are still found in limited quantities. Although the mining has taken its toll from the landscape in places, it has added a special interest. The visitor is amazed to see mine buildings perched high on almost sheer mountainsides, thrilled by finding pieces of rock containing silver or some other mineral in old mine dumps, and awed by the strip mining on top of Red Mountain, elevation 12,865.

Lake San Cristobal at the head of Lake Fork of the Gunnison River is a popular recreation area,

and Lake City, a former mining town, has been converted into a resort center. Ouray, a county seat which prospered during the heyday of mining, is beginning to realize that its future economic life will depend to a large extent on the wise use of the recreational resources. The town is ideally suited to serve as a center for vacationists, being situated in a beautiful little basin surrounded by colorful high mountains.

The town of Silverton retains much of its original flavor. Most of its construction took place 40 to 50 years ago and little modernization has taken place. It is an interesting representation of an era in the development of the Rocky Mountain region. The setting of the town, 9,300 feet above sea level, is dramatic. Bleak, high, rugged mountains enclose the narrow valley floor on which the town rests.

There are few roads in the San Juan-San Miguel-Uncompahgre area, but trails lead to the high country from the roads that approach the area from the north and south and from United States Highway 550. Fishing, hunting, hiking, mountain climbing, horseback riding, and camping are the main recreational activities. A branch of the Denver & Rio Grande Railroad follows the Animas River from Durango to Silverton, another follows the Uncompahgre River from Montrose to Ouray, and a third runs southwest from Ouray to Telluride and down the Dolores River to Dolores, Colo., near Mesa Verde National Park. Trips on these narrow-gage railroads are capable of being developed into a major tourist attraction.

Most of the area is included within the boundaries of the San Juan, Montezuma, and Uncompahgre National Forests and the higher, more remote portions of each have been designated as primitive areas. There is some virgin forest, but the bulk of the timber within the area has little value for timber production. Its primary value is watershed protection. Mining has been important in the past. In the future, recreation probably will be the major value of the area.

2. Elk Mountain area in the White River and Gunnison National Forests is bordered on the north by State Highway 82 which crosses the Continental Divide near its highest point at Independence Pass, elevation 12,095 feet. The highway is unexcelled for the views it affords of lofty moun-

Figure 117.—View of Silverton, Colo., from United States Highway 550.

tains, tumbling snow-fed streams, and forests of pine and aspen. The streams are among the best in the State for fishing.

West of Independence Pass, State Highway 82 descends into the valley of the Roaring Fork River by easy grades. Aspen, an early mining town located in the valley of the Roaring Fork at an elevation of 7,850 feet, now attracts many visitors who take advantage of the 1,000 miles of trout streams and 25 lakes within a short radius. Dude ranches in the vicinity have access to trails that lead in all directions. In recent years, Aspen has become a popular winter sports center. Just west of Aspen a dirt road leads south along Maroon Creek to Maroon Lake, known for its magnificent mountain setting and excellent fishing.

South of the Elk Mountains region is the town of Crested Butte, elevation 8,867 feet, from which State Highway 135 ascends to Kebler Pass directly north of West Elk Peak. A dirt road leads to Gothic, 9 miles north of Crested Butte, where the Rocky Mountain Biological Laboratory is located.

Near Kebler Pass, at the foot of Ruby Peak, Lake Brennan rests in a pocket on the mountainside, surrounded by a luxuriant growth of alpine-type plants. Further north, Snowmass Mountain, Maroon Peak, and Castle Peak rise majestically to elevations above 14,000 feet. Beyond Kebler Pass, Route 135 crosses a high plateau covered by an abundant growth of flowers, grasses, shrubs, and trees. Dense stands of conifers alternate with aspen-fringed meadows to provide an expanse of charming mountain scenery. The high peaks nearby add to the superlative quality of the landscape. The recreational opportunities of this region seem almost unlimited.

3. The Park Range, located in the extreme northern section of Colorado, with its numerous high peaks and its wooded slopes, offers many possibilities for public enjoyment. Steamboat Springs, located at the foot of the range on the Yampa River, is a popular year-round recreation center. United States Highway 40 provides access to the region and State Highway 129 skirts the mountains on the west to lead to the Hahns Peak country, one of the excellent hunting and fishing areas in the State.

4. White River Plateau in the White River National Forest is one of the fine recreational areas in Colorado, ranging in altitude from 9,000 to 11,000 feet above sea level. Shingle Peak and Sheep Mountain are more than 12,000 feet. The plateau has a delightful cool summer climate. Numerous lakes and streams in a forest setting provide good trout fishing and pleasant camp sites. Deer and elk are plentiful. Trappers Lake, the largest lake in the area, is a summer resort. The main approach by road is from Meeker, Colo., on the west. Other roads lead to the area from the Steamboat Springs region. Trails from Glenwood Springs climb up to the plateau. The central portion of the forest has been designated as the Flat Tops Wilderness Area.

5. The Gore Range south of the Park Range is bordered by State Highway No. 9 along the Blue River, a popular fishing stream. The high crags and deep woods make the Gore Range a valuable recreational area for Colorado.

6. The Grand Mesa, east of Grand Junction, Colo., is 900 square miles in extent and rises 5,000 feet above the surrounding country in splendid isolation. Hundreds of small lakes dot the mesa and many of them provide excellent fishing. State Highway 65 leads to the top of the mesa and provides many interesting views of mountain lakes, meadows spangled with wildflowers, aspen groves, and fir and spruce forests. Deer and small game abound in the area.

Dams have been constructed at the outlets of most of the larger lakes to increase their storage capacities. Resorts and summer homes have become established on several of the more accessible lakes and Forest Service camp grounds are available. The Grand Mesa area is especially important in providing cool recreation grounds for persons living in the valleys of Delta and Mesa Counties, Colo.

UTAH

1. Uinta Mountains. Though now known best by geologists, foresters, and a few fishermen, hunters, and stockmen, the fascinating scenery of the Uintas seems destined to receive much attention. Few areas of comparable size present such a diversified landscape—lofty, bright-colored canyon walls, and giant hogbacks along the borders; and beautiful lakes and streams in the forested uplands.

The Granddaddy Lakes region of the Uinta Mountains, including to the westward the head-

water basin of the Duchesne River and to the eastward most of the primitive area of the Wasatch and Ashley National Forests, is one of the most notable and valuable recreational areas in the entire northwestern part of the Colorado River Basin.

The factors which give the region its particular value are numerous and complex. There are many craggy peaks more than 12,000 feet in altitude, and intervening lands of comparatively gentle slopes, at altitudes of more than 10,000 feet. These high lands are cool in summer. They are shaded by forests mainly of spruce, fir, and pine, are abundantly watered by clear streams, and contain a profusion of small glacial lakes with excellent fishing. Granddaddy Lake, at an altitude of 10,300 feet and with a water surface of 170 acres, is one of the largest lakes in the Uinta Mountains. Another feature of the area is the fact that the steepness and ruggedness of slopes and valleys descending from this high area toward the surrounding habitable lands have thus far halted the penetration of roads, even the roughest of wheel tracks, beyond its outer borders. It has been left completely free from the exploitations and irritating reminders of a mechanized civilization that follows wheeled vehicles. By short trail trips from roads that come to its borders, people can plunge into a wilderness contrasting completely with the adjacent country.

2. The Aquarius Plateau-Boulder Mountain area in south-central Utah is a little-known but potentially important recreational area. Numerous ponds and lakes dot the forest-covered tableland of 70 square miles that ranges in altitude from 10,000 to 11,000 feet. From numerous points there are grand views of the colorful lower plateaus stepping down to the Colorado River, the sheer-walled canyons of the Escalante River and its numerous tributaries, the Henry Mountains, the Waterpocket Fold, and the Circle Cliffs. The plateau, with the adjoining canyon lands on the east, provides a combination of scenic and recreational interests ranging from colorful deserts to high cool boreal forests. There is trout fishing in the lakes and streams and deer, elk, and cougar hunting on the plateau.

State Highway 23 on the south and State Highway 24 on the north provide access to the area. A county and U. S. Forest Service road connecting Escalante, on Highway 23, and Torrey, on High-

Figure 118.—Mirror Lake Basin just west of the high Uinta Primitive Area.

way 20, crosses the east side of the area. It is the most scenic drive in southeastern Utah. Between Escalante and Boulder, the road crosses the Escalante River Canyon and runs along the top of narrow ridges between deep, sheer-walled canyons and provides exceptional views of the colorful desert canyon lands and the high forested plateau. Between Boulder and Torrey the road climbs over the east side of Boulder Mountain. Deep snow makes this section of the road impassable in winter.

3. Monument Valley, intersected by the Utah-Arizona line, is in the north central section of the Navajo Indian Reservation. Utah State Highway 47 crosses the area on its way from Mexican Hat to Kayenta, Ariz. The comparatively level plain rises from altitudes of about 5,000 feet to 5,700 feet at Monument Pass. Individual buttes rise to heights nearly 1,000 feet above the plain.

Monument Valley is the result of a stupendous erosion process that has left weird, wind-blown monoliths, spires, and totem poles standing hundreds of feet above the vast vivid-hued desert floor. Clouds, shadows, and moonlight transpose the forms and colors to create phantasies that are overwhelming. It is an area that should be retained in its desert wilderness character unspoiled by the evidences of modern civilization.

4. Nine Mile Canyon, northeast of Price, contains valuable prehistoric ruins and picture writings. Four types of Pueblo houses have been found here. The area is approached over State Road 53 which leaves United States Highway 50, 10 miles east of Price.

5. Poncho House, located about 15 miles east of Monument Valley, is one of the major cliff dwelling villages in the Southwest.

6. Westwater Ruins, 5 miles southwest of Blanding, and easily accessible, contain ancient cliff dwellings and an attractive site for picknicking.

7. The Old Cotton Mills at Washington near St. George is a well-preserved building, erected in 1866 for spinning "Dixie Cotton" in the early days of Utah history.

NEW MEXICO

1. Manuelito National Monument Project, bordering the Santa Fe Railroad and United States Highway 66 between Manuelito, N. Mex., and Lupton, Ariz., 17 miles southwest of Gallup, N. Mex., is an impressive archeological, geological, and scenic area proposed for inclusion in the National Park System.

2. Gila Primitive Area in southwestern New Mexico is the largest and most beautiful unspoiled wilderness in the Southwest. Elevations extend from 4,500 feet to peaks more than 10,000 feet. The highest peak, Whitewater Baldy, is 10,892 feet high. No settlements are located within the area, but there are several dude ranches. The wilderness area is fairly well provided with trails, but the area as a whole is practically free from improved roads.

The outstanding topographic feature of the Gila Primitive Area consists of four deep canyons trenched deep into the eastward-sloping plateau by the Gila River and its three head tributaries. Practically all of the rocks exposed on the surface are of volcanic origin. Perhaps the most striking geologic feature is the great number and variety of erosion forms. The volcanic rock acted upon by water, wind, and frost has produced hundreds of unusual and grotesque shapes. The primitive area contains a number of thermal springs. Eight are classified as warm springs and two as hot springs.

The greater part of the area is forested and is preeminently a wildlife country. Large game animals are plentiful and there are many flocks of wild turkey, quail, and other game birds. The canyons are a haven for song birds and the streams teem with trout.

There are numerous archeological sites within the area. Gila Cliff Dwellings National Monument, where are preserved spectacular cliff dwellings set in a unique cave in a vertical cliff, is located in the east-central portion of the primitive area. This area has a very livable summer climate with unusually cool nights for its southern location. It has unlimited resources for recreation, study, and research. With proper development, the area could accommodate a large number of visitors without spoiling its primitive character.

ARIZONA

1. Coronado International Memorial Project. The act of August 18, 1941, (55 Stat. 630), authorizes the President to establish this memorial by proclamation when he has been advised that the

Government of Mexico has established, or provided for the establishment of, an area of similar type and size adjoining the area described in the act. The purpose of the proposed project is to commemorate the Coronado Expedition, a significant event in North American history. The area chosen lies partly in Cochise County, Ariz., and partly in Mexico.

2. Meteor Crater, one of the most remarkable features in the United States, is famed throughout the world. It is situated in Coconino County, Ariz., in the southern portion of the Colorado Plateau. The crater may be reached by traveling 18 miles west of Winslow on United States Highway 66 and 4 miles south on a dirt road.

The irregular rim of the huge crater, nearly a mile in diameter, rises more than 150 feet above the surrounding plain. The main portion of the rim at an elevation of 5,800 feet is more than 1,000 feet in width, with scattered remnants of debris as much as 6 miles from the crater. The crater floor is flat and approximately 1,500 feet across. There has been considerable speculation as to the probable origin of the crater. Most of the evidence points to a meteoric impact.

Regardless of the origin, the crater contains much in the way of inspirational appeal. If it is the result of an impact of a meteor, as is now generally conceived, it is the largest known crater in the world formed by such a phenomenon.

3. Fort Bowie named, in all probability, for Brig. Gen. George W. Bowie, is located in Apache Pass in the Chiricahua Mountains of southeastern Arizona. It is one of the most famous historic United States forts in the Southwest. Established in 1862, its fame was largely in connection with campaigns against the Apache Chieftain Cochise during the 1860's and early 1870's and the renegade leader, Geronimo, during the late 1870's and the 1880's. With the surrender of Geronimo in 1886, there was no further need for Fort Bowie and from that time to the present it has gradually crumbled into a state of ruin. Few forts in the western part of the United States experienced such an exciting and dramatic career.

The site is reached by traveling 14 miles over a dirt road from the town of Bowie. The elevation at the site is about 4,700 feet. The story of Fort Bowie falls logically into the national theme of "Westward Expansion and the Extension of National Boundaries 1830-90." As a part of that theme, it played an important part in protecting the frontier settler and traveler.

4. Kinishba Ruins on the Fort Apache Indian Reservation is about 16 miles south of McNary, Ariz., 1.5 miles north of State Highway No. 73. It is at an elevation of some 5,400 feet, in the midst of the camps of the Apaches.

Kinishba was the center for a number of developments in pottery making in the Upper Salt and Little Colorado area. Kinishba seems to be the largest continuously occupied pueblo in the area in question. It has been partly restored under the direction of Dean Cummings of the University of Arizona, with Indian enrollees of the Civilian Conservation Corps furnishing the labor, and partly with funds privately donated. The 45-acre tract is well fenced and includes a museum and quarters building.

5. Clear Creek Ruins are located on Clear Creek about 5 miles south of Montezuma Castle National Monument in central Arizona, within the Coconino National Forest. They are of national significance.

The big ruin atop a ridge north of the confluence of Clear Creek with the Verde River is one of the largest ruins in the Verde Valley. The main portion, comprising some 50 ground floor rooms, is built of limestone and caliche. A number of walls are standing to first-story level; originally, the ruin was at least two-storied. There are 40 or more cave rooms and small cliff dwellings on the south side of the ridge, below and east of the main ruin. The site covers some 30 acres.

6. Chaves Pass Ruins located in the eastern portion of the Coconino National Forest in the Anderson Mesa country some 35 miles southeast of Flagstaff, Ariz., constitutes an archeological site of unusual scientific historical importance. The site is on a good dry-weather road which leaves United States Highway 66 at Meteor Crater Junction and goes south past Meteor Crater to Chaves Pass about 40 miles from the highway. Chaves Pass is one of the few breaks through which aboriginal travel between the Little Colorado and the Mogollon Rim country would have been easy. A number of small lakes are within 5 miles. Vegetation is sparse at the site, but there is a good growth of piñon and juniper and some ponderosa pine in the vicinity.

The Chaves Pass Ruins include two large building blocks of pueblo type, a ball court, and remains of various smaller structures.

The mesa point on which the main Chaves Pass Ruins are situated evidently was occupied more or less continuously from around 1100 A.D. until 1400 A.D.

7. Awatovi, site of the Mission of San Bernardino, is located on the north side of Jeddito Valley in the south central portion of the Hopi Indian Reservation near the settlement of Keams Canyon. It was one of the largest and most important of the sixteenth and seventeenth century villages of Tusayan, the first one reached by expeditions, and the one most often mentioned in early chronicles. The ruin is in fair condition and extends for a quarter of a mile along the mesa top, and back from the edge for a distance of 250 to 300 yards. Little survives of the mission, founded in 1629. Excavations have been carried on under the direction of the Peabody Museum of Harvard University.

8. The Blue Range area lying largely in Arizona, with a small part extending into New Mexico, includes more than 218,000 acres. It is one of the few remaining large areas of forest land in the Southwest still without roads. It is a region important for its big game and its trout streams, is accessible only by trails, and is the largest available area free from human occupancy and development in the State of Arizona. It extends into New Mexico to within a few miles of the Gila Primitive Area. The area is traversed from east to west by the Mogollon Rim, an abrupt escarpment-like topographic feature forming the southern boundary of the Colorado Plateau. The area above the rim is in the Boreal Zone, while below the rim is a wild and broken country largely in the Transition Zone. Elevations range from 4,500 to more than 9,100 feet. The area's major values are for the protection of the Gila and Salt River watersheds and for public recreation.

9. The Mount Baldy-White Mountain area in east central Arizona adjacent to United States Highways 666 and 73, ranges from 8,700 feet to 11,496 feet above sea level. The topography varies from gently sloping bench at the foot of Mount Baldy to extremely steep, rock-strewn mountainsides cut by deep canyons.

Geological features of spectacular character, including numerous lofty peaks and deep canyons, offer great possibilities for recreational development in the White Mountain area. High altitudes with cool climate, well-forested surfaces, and numerous clear mountain streams where trout fishing is good all tend to make this an excellent summer resort area. Few other localities in Arizona are comparable in quality, and none is nearly as extensive. Development along recreational lines has been considerable during recent years, but only a beginning has been made in the construction of trail systems and camps. Ultimately, this area must be used to meet extensive needs and demands for summer recreation of the people living in the hot lowlands of Arizona.

10. San Franciscan volcanic field. Many geological features of unusual character and general interest are found in the San Francisco Mountains and the surrounding volcanic field. Because of the high altitude of the area, with resulting cool summer climate, this region offers tremendous possibilities for the development of attractive trails to features of scientific interest and for the interpretation of such features through appropriate signs or labels. A start in this direction has already been made by the Forest Service and the National Park Service in their respective areas, but much remains to be accomplished in the utilization of recreational possibilities. This area might be made into one of the fine recreational centers in the basin, especially for horseback riding and hiking.

11. The Mogollon Rim area is located south of United States Highway 66 and extends from a point southeast of Flagstaff, Ariz. to the White Mountains near the New Mexico line.

The rim is the crest of the plateau that divides Arizona into two physiographic provinces—the Colorado Plateau on the north, and the basin and range province on the south. From the Mogollon Rim the drainage is north into the Little Colorado River and south into the Salt, Tonto, and Verde Rivers. The slope to the north is gradual for a distance of 50 miles. To the south the slope is rugged and abrupt, with a fall of 1,500 to 2,000 feet within a distance of a few miles. The greater part of the Mogollon Rim is heavily timbered, with ponderosa pine predominating. Near the crest one

finds aspen and spruce; on the lower slopes are piñon and juniper.

An outstanding feature of the area is Clear Creek Canyon. It varies in depth from 400 to 800 feet and in places is less wide than deep. It is practically invisible from any point more than a quarter mile from the rim.

12. Travertine Bridge is located in the central part of Arizona in the Tonto National Forest. The bridge is unique in being composed of travertine rather than sandstone from which most natural bridges are formed. The upper surface of the bridge is approximately 400 feet long and rises about 150 feet above the bottom of the canyon. How the bridge was formed is a matter of conjecture at this time. Not only is the bridge unique in respect to origin, but it is one of the most beautiful natural bridges in the United States. Wildlife is abundant and the area abounds in prehistoric pueblos, practically all unexcavated.

The bridge is located in very rugged country, and roads through this section of Arizona are of a low standard. The elevation of the bridge in the bottom of Pine Canyon is 4,600 feet above sea level.

13. The Apache Trail—Superstition Mountains area in the Tonto National Forest approximately 40 miles east of Phoenix, Ariz., is of major importance to the people living in south central Arizona. It includes four reservoirs, a scenic highway, and an excellent and varied landscape of mountain peaks, mesas, canyons, cliffs, interesting vegetation, and considerable color. Boating and fishing are available on the reservoirs and accommodations for visitors are provided by private interests.

The main road, known as the Apache Trail, from Roosevelt Lake down the Salt River, skirts the north boundary of the Superstition Wilderness Area. Several roads end within a half mile of the boundary of this wilderness area. Further access is gained by an incomplete system of trails.

14. Oak Creek Canyon is traversed by United States Highway 89. South of Flagstaff, Ariz., the highway drops from an elevation of 7,000 feet to 2,500 feet in lower Oak Creek Canyon. Lookout Point at the head of Oak Creek Canyon, 13 miles south of Flagstaff, is approximately 2,000 feet above the stream bed. The grandeur of the massive canyon walls is enhanced by the many colored ledges and buttes, while the canyon floor abounds in wild flowers.

Oak Creek Canyon was formed by the faulting of Coconino sandstone. This fault, which is apparent—the wall on the right being higher than that on the left—extended for many miles and formed an opening for great volcanic activity. A cap of basalt is visible along both rims at the upper end of the canyon.

Approximately 22 miles from Flagstaff, the color of the sandstone changes from white to red. Scrub oak and buckbrush replace mountain pines. A mile further, a panorama includes the trout stream, steep red cliffs, and the widening bottom lands to the south.

With the construction of the highway have come lodges, tourist camps, swimming pools, and other signs of civilization, in an area that prior to 1930 had been a wilderness retreat.

15. The Kofa Mountains in southwestern Arizona are more scenic than most of the mountain ranges in that section of the State. The highest point, Signal Peak, rises to an elevation of 4,200 feet, some 2,600 feet above the plain. There are precipitous cliffs and gorge-like canyons in this range. A feature of special interest is the grove of native palms growing in a steep narrow ravine, near Signal Peak.

This part of the Kofa Mountains is seldom visited due largely to a lack of drinking water and the excessive heat during the summer months. In addition to the palms and other interesting forms of plant life, the presence of bighorn sheep add interest to the area.

State Highway 95, a fairly good desert road, provides access to the region.

16. Southeastern Arizona Ranges. This portion of Arizona, more than any other, has been developed along recreational lines. The desert valleys between ranges have long been recognized as vacation centers for winter visitors and certain of the higher ranges which are well forested are being used for summer resorts. The Santa Catalinas are an example. Here, as elsewhere in the mountains, the chief difficulty is found in the rather limited space available for development. On the other hand, there is much opportunity for trail development and, to some extent, development of roads

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to points of unusual interest and significance, especially in the higher, forest-covered ranges.

Geological features of interest are apparent in many parts of this vast area. The semiarid climate causes most outcrops to remain fresh and the vegetative cover to be reduced to a minimum. Thus, complexities of structure and details of rock character are readily observable. Under such conditions it is natural that a large number of persons residing within the region should take a lively interest in geology. One of the principal needs in this connection is the availability of authentic information concerning features of interest. In any program of recreational development careful consideration should be given to ways and means of presenting such information.

NEVADA

1. Hidden Forest in Clark County is a scenic area of virgin timber in a desert region. Approximately 5,760 acres would be suitable for a State park, providing opportunities for sports, camping, and picnicking, as well as relief from the desert heat.

2. Gypsum Cave, about 16 miles east of Las Vegas, Nev., is a large cavern in limestone, about 300 feet long and 120 feet wide, containing cultural material associated with bones of the ground sloth and other extinct fauna underneath Basketmaker and later remains. An antiquity of more than 5,000 years has been calculated on the basis of remains of the "sloth people."

CALIFORNIA

1. Palm Canyon, 7 miles south of Palm Springs, Calif., has been authorized for addition to the National Park System as a national monument when the necessary lands are made available. Here the native Washington-palms are found in abundance over the length of the 14-mile-long canyon. At the upper end of the canyon, a mile and a half beyond the limits of the palms, a 60-foot waterfall starts a crystal clear stream on its way between the rugged white caliche canyon walls. An excellent horse trail follows the east wall, providing views of the many palm groves with their associated desert plant forms.

2. Giant pictographs, works of early inhabitants, are found throughout the lower basin of the Colorado River and adjacent desert areas. Relief designs were made by raking or stacking gravel in lines or piles, and intaglio designs by taking out sections of the black surface cobbles which exposed the light-colored subsurface. The oldest ones may have been produced by prolonged stamping of feet on the gravel surface, after it had been made soft by heavy rains. The figures represent geometric patterns and life forms. Those of the latter type are of the freshest appearance, probably of Yuman origin.

RECREATION CENTERS

The recommendation made for the Canyon Lands of southeastern Utah—that facilities for the accommodation of travelers and vacationists be concentrated in or near existing towns and villages so that the great areas of open country can remain free of scattered reminders of town life—has general application to the entire basin. Such action would help to maintain conditions which attracted the people now living in the basin and will attract people more and more from the sections of the United States where little undeveloped or uncultivated lands remain. It would also help to maintain and stimulate the economic life of existing communities.

Many of the towns are now focal points for recreational use of the surrounding country. Some of the outstanding one are:

COLORADO

1. Steamboat Springs, in the north central part of the State, is a gathering place for the many visitors to the medicinal springs and pools about the town and to the trout streams and lakes in the vicinity. Skiing is an important attraction in this region. A winter carnival is an annual event in this community.

2. Glenwood Springs, in northwest Colorado, has an immense hot mineral water outdoor swimming pool and an extensive ski course development. The scenic wooded mountains in the region abound in fishing streams and hunting areas.

3. Gunnison, in west central Colorado, provides

accommodations for the numerous fishermen and hunters who visit the region. Some of the most celebrated fishing streams in the United States are in the locality. A Cattlemen's Day and a Sportsmen's Tournament are annual events in the community.

4. Durango is in the center of an important recreational region in southwestern Colorado. Beautiful, wooded mountains lie to the north and east where dude ranches, fishing streams, and hunting areas are plentiful. High-standard roads lead in each direction to scenic country.

Many other towns in Colorado have excellent possibilities for development as recreation centers.

ARIZONA

1. Phoenix, at an elevation of 1,080 feet, with a population swelling to more than 150,000, is a desert metropolis located in a rich, irrigated agricultural area. Mountains appear on the horizon on all sides. The warm winter sunshine attracts thousands of visitors. The highlight of the tourist season is the Festival of the Sun held the last week in March.

Points of interest in the vicinity of Phoenix are Papago State Park, Phoenix South Mountain Park, the Pueblo Grande Ruins and laboratory, and the many fine hotels and guest ranches.

2. Tucson, at an elevation of 2,376 feet, has a population of about 40,000 .It is a health and winter resort that has grown up around one of the oldest Spanish towns in the United States. Tucson residents engage in sports of all sorts and take part in music and art programs fostered by the State University located within the city limits. Riding over trails in the wide desert expanses is a favorite pastime.

In the vicinity of Tucson are many points of interest including Tucson Mountain County Park to the west, San Xavier Mission south of town, and the Santa Catalina Mountains and Saguaro National Monument to the east. The Yaqui Indian villages and ruins of Fort Lowell are other attractions close to town.

Tucson Mountain Park is especially attractive, its 44 square miles of desert mountain country containing a wealth of desert growth and an abundance of wildlife.

3. Prescott, elevation 5,347 feet, has a population of more than 6,000. It is in the mountainous section of west-central Arizona. Forests of pines south and west of town contribute to Prescott's growing popularity as a summer resort in the heart of the dude ranch country. For 3 days each summer Prescott is given over completely to a Frontier Days Rodeo. Fort Whipple and Yavapai Indian Reservation, Hassayampa Mountain Club in the Presscott National Forest, and Granite Dells are points of interest in the vicinity.

4. Flagstaff, at an elevation of 6,900 feet and with a population of 5,000, is surrounded by outstanding natural scenery. Southward are the gorges and canyons of Oak Creek. Mans Hill, a low mesa running north and south, forms a green background on the west, and on the northwest dark Mount Elden rises above the town. Beyond Mount Elden are the massive, lofty San Francisco Peaks.

Each year Flagstaff holds a pow-wow during the first week of July, which transforms the town into an Indian village. Several thousand Indians representing 20 tribal nations take part.

Nearby points of interest are Sunset Crater, Wupatki, and Walnut Canyon National Monuments, Lowell Observatory, and the Museum of Northern Arizona.

5. Winslow, on United States Highway 66, is a gateway to the Navajo and Hopi Indian Reservations to the north and to the Mogollon Plateau and the Tonto Basin to the south.

6. Williams is a southern gateway to Grand Canyon National Park.

7. Wickenburg is known as the Dude Ranch Capital.

UTAH

Although there are few towns in Utah within the Colorado River Basin that at present can be considered as important recreation centers, there are several with great potentialities in this direction.

1. St. George, Hurricane, and Springdale in the Virgin River Valley are well situated to become major centers. The Virgin Valley and adjacent plateaus and mountains offer a wide variety of unusually colorful scenery, a range of life zones with the accompanying range of flora from lower Sono-

ran to Boreal within a space of a few miles, and a corresponding range of climatic conditions. The valley's particular charm is a combination of well-cared-for villages, green fields and orchards, and wild, brilliantly colored cliffs, deep canyons, black mesas, and forest-covered mountains.

2. Moab is in a somewhat similar setting and is destined to become an important center for persons visiting the unusual country around it.

3. Vernal, Torrey, Escalante, and Blanding are all gateway towns to major areas of recreational interest.

4. Kanab is now an important center for moving picture companies taking pictures of outdoor scenes.

WYOMING

Pinedale is the natural center for the recreational use of the west side of the Wind River Mountains.

CALIFORNIA

Palm Springs has already developed as a famous desert winter recreation center that features swimming, bicycling, and sun-bathing. The major portion of the population of the Los Angeles region is within a 3-hour drive of Palm Springs. San Bernardino National Forest, Mount San Jacinto, and Anza Desert State Parks, and Joshua Tree National Monument are all within an hour's drive of Palm Springs.

NEVADA

1. Boulder City, the headquarters for the government agencies concerned with the operation and administration of Hoover Dam and the Lake Mead area, is also an important gathering place for visitors. Tourist accommodations are provided in the town and on the shore of Lake Mead.

2. Las Vegas is a popular tourist center with a number of resorts, hotels, and entertainment and gambling establishments.

ROADSIDES

One of the pleasant features of the basin at present is the opportunity to drive for miles along roads that are not paralleled by fences and pole lines. However, more and more fences are being built along roads as part of the Bureau of Land Man

Figure 119.—Signs, pole lines, and wide right-of-way clearing detract from the enjoyment of the natural scene.

agement program of range management. Admittedly, it is essential to fence high-speed highways against the danger of wandering livestock, but there are many miles of secondary roads which need not be fenced. It is suggested that, wherever possible, grazing allotments or grazing units be adjusted so that they include both sides of secondary roads. This would eliminate the necessity of unit boundary fences paralleling such roads. An occasional cattle guard and fence across the road make the traveler feel he is in the range, whereas continuous paralleling fences set him apart from the country he is traversing.

On the same basis, the clearing and grading for roads should be limited to the narrowest possible width compatible with good road construction. A great wide gash across the country sets the traveler apart from the landscape just the same as a high wire fence. He may get the fine views of country but he does not have the feeling of being in it. This is particularly true in a forested area.

SCENIC ROADS

While there is hardly a road in the basin that does not afford some scenic interest, there are certain roads or sections of roads which during the course of the survey have been noted as outstanding and worthy of special attention. They are described below and are indicated on Plate 16 (in pocket).

ARIZONA

United States Highway 89, from Nogales to Florence, passes through fine desert country and cultivated valleys. Points of interest include: Tubac, the oldest town in Arizona; Tumacacori Mission, built in 1690; San Xavier Mission, built in 1692; and the cities of Tucson and Nogales.

State Highways 82 and 83, from Nogales to Vail Junction on United States Highway 80, have fine desert mountain scenery and pass old Fort Crittenden.

United States Highway 84, from Redrock to Gila, is in open desert country. Interesting features are: Picacho Pass, Casa Grande Mountains, and Maricopa Mountains.

United States Highway 70, between Apache Junction and the head of San Carlos Lake, passes through the Crook National Forest and the mining towns of Superior, Miami, and Globe. Where it crosses the Coolidge Dam, it opens to view a wide variety of Arizona scenery.

State Highway 88—the Apache Trail—is a spectacularly scenic drive through the Tonto and Crook National Forests, and along the shores of Canyon, Apache, and Roosevelt Lakes.

United States Highway 60, between Globe and Showlow, passes through the Crook National Forest and the Fort Apache Indian Reservation. The crossing of Salt River Canyon is a spectacular feature.

State Highway 77, from Showlow to White River, is in the impressive Mogollon Rim country of the Fort Apache Indian Reservation.

State Highway 73, between McNary and Springerville, is through fine White Mountain scenery, the Fort Apache Indian Reservation, and Apache National Forest.

United States Highway 666, from Springerville to Clifton, is part of the Coronado Trail.

United States Highways 89 and 89A pass through the Prescott and Coconino National Forests and by such interesting features as the Granite Dells, Oak Creek Canyon, San Francisco Mountains, Verde Valley mining towns, and Tuzigoot, Walnut Canyon, Sunset Crater, and Wupatki National Monuments.

United States Highway 66 passes through the Kaibab and Coconino National Forests. The high, forest-covered plateau, with splendid contrast to the tains and desert valleys, is a pleasant contrast to the long desert sections of the highway.

United States Highway 89, from Cameron to Kanab, Utah, passes through the Navajo Indian Reservation and over the Kaibab Plateau. The colorful Painted Desert, Marble Gorge of the Colorado River, House Rock Valley, and vermilion cliffs of the Paria Plateau are interesting features.

Rainbow Trail, in the Navajo Indian Reservation between Tonalea and Rainbow Lodge, offers views of spectacular canyon scenery.

The road from Kayenta, Ariz. to Mexican Hat, Utah, is through the fantastic Monument Valley.

UTAH

State Highway 95 from Blanding to Natural Bridges National Monument crosses Elk Ridge,

affording fine views of Arch Canyon and Grand Gulch Plateau.

United States Highway 160 and State Highway 47 from Moab to Monticello pass through highly colorful sandstone country and offer fine views of Abajo and Elk Mountains.

State Highway 128 from Moab to Dewey Bridge follows the Colorado River through an impressive canyon.

United States Highway 89 and State Highway 15 from Kanab to Toquerville pass through Zion National Park and other spectacular scenery.

The road from Escalante through Boulder to Torrey is one of the most scenic drives in Utah.

State Highway 44 from Vernal to Linwood, through the Ashley National Forest, crosses the Uinta Mountains. There is unusually fine scenery in the vicinity of Sheep Creek.

COLORADO

United States Highway 550 between Durango and Ouray is in the spectacular high mountain country of the San Juan and Uncompahgre National Forests.

State Highway 82, Glenwood Springs to Twin Lakes, crosses the Continental Divide at Independence Pass, elevation 12,095.

State Highway 135, from Almont to Somerset, climbs over the scenic Elk Mountains.

United States Highway 160, between Pagosa Springs and Baxterville, climbs over the beautiful San Juan Mountains.

ROADLESS AREAS

While it will be necessary to construct new roads and improve existing ones in order to develop the resources of the basin, it must not be forgotten that the large areas in which there are no roads comprise one of the basin's great recreational assets. The Bureau of Indian Affairs, the Forest Service, and the National Park Service have recognized this by establishing roadless areas. Other roadless areas might well be established. The point is well stated in the Order of the Bureau of Indian Affairs dated October 25, 1937, establishing roadless and wild areas on Indian reservations:

> Mechanization is growing in America with unprecedented acceleration. Activity after activity which for countless generations have been performed directly by manpower and area after area which have been subject only to the forces of nature are now dominated by machinery. To millions of Americans this constitutes an unmitigated blessing.
>
> There are other millions who, while they appreciate the good which the machine can bring, also have an intense craving for another type of existence. They do not see why their life must be lived entirely in the world of machinery when there is ample space in this great country for another world as well. They cannot believe that with vast stretches which need not be used for the mechanical activities of our civilization, it is necessary to make every nook and corner of the country a part of the machine world and to wipe out all sizeable traces of the primitive.
>
> It is perfectly feasible to reserve for such people something of those wilderness values which they crave. A little advance planning and a little balancing of the claims of genuine conflicting values will make it possible to save many areas from mechanization. In the past a great many ideal wilderness areas have been opened by roads which were of no necessity and which have never returned in value of service anywhere near the investment which has been put into them. Had there been a little prior thought about a reasonable balance between primitive and developed areas, these roads would not have been constructed.

Type of area and name	Acreage[1]	Outstanding characteristics
WYOMING		
National Forests:		
Bridger	1,699,098	Impressive high mountain scenery of the Wind River Range. Beautiful natural lakes and streams.
Medicine Bow	1,064,706	Developed camp and picnic areas; several winter sports areas in the Snowy Range; excellent hunting and fishing; saddle-pack trips; impressive scenery.
COLORADO		
National Parks:		
Mesa Verde	51,018	Most notable and best preserved prehistoric cliff dwellings and other structures in the United States.
Rocky Mountain	252,626	One of the most magnificent and diversified sections of the Rocky Mountains, with 65 named peaks in excess of 10,000 feet.
National Monuments:		
Black Canyon of the Gunnison	13,176	Remarkable deep narrow canyon with sheer rocks of great geologic interest so altered through compression and lava intrusion that their origin is in doubt.
Colorado	18,121	Sheer-walled canyons, towering monoliths, and weird formations hewed by erosion in sandstone.
Dinosaur	[2]190,798	Nation's richest fossil quarries containing skeletal remains of giant reptiles and other creatures of remote geologic time, preserved in excellent condition.
Holy Cross	1,392	Two crevices on side of Mount of Holy Cross, which, when filled with snow, form a cross.
Hovenweep	[3]299	Four groups of remarkable prehistoric towers, pueblos, and cliff dwellings.
Yucca House	10	Remnants of once thriving prehistoric Indian Village.
National Forests:		
Arapaho	971,879	Scenic Gore Mountains: Gore Range-Eagle Nest Wild Area; winter sports area; glaciers, mineral springs; big and small game; trout streams.
Grand Mesa	652,681	Grand Mesa Plateau—34,000 acres more than 10,500 feet high. Two hundred and fifty lakes and reservoirs. Cliffs, canyons, and waterfalls.
Gunnison	1,472,327	Numerous peaks more than 12,000 feet high. Many miles of trout streams. Storm Ridge Wilderness Area and Maroon Bells—Snowmass Wilderness Area, Gothic Natural Area. High scenic drives.
Montezuma	757,371	Mount Wilson, 14,250 feet. Lakes, canyons, waterfalls, and peculiar geologic formations. Virgin ponderosa pine. Narraguinnep Canyon Natural Area. Wilson Mountains Wild Area. Trout streams and big game.
Routt	997,627	High mountain country with trout streams and alpine lakes. Mount Zirkle-Dome Peak Wild Area. Winter sports area.
San Juan	1,248,860	Several peaks more than 14,000 feet high. Picturesque canyons and alpine lakes. Historic mines. San Juan Wilderness Area. Trout streams and big game.
Uncompahgre	788,309	Numerous peaks in excess of 13,000 feet. Uncompahgre Plateau. Gold mines. Uncompahgre Wild Area. Ouray Scenic Area.
White River	1,984,603	Spectacular Glenwood Canyon. Mineral hot springs, caves, lakes, and trout streams. Flat Tops Wilderness Area.
UTAH		
National Parks:		
Bryce Canyon	36,010	Rocks among the most colorful of any of the earth's crust, exposed on the side of a plateau and shaped by erosion into pinnacles and grotesque forms.
Zion	94,241	Multicolored gorge in heart of southern Utah's dramatic desert and canyon country; erosional formations of great height and spectacular carving.
National Monuments:		
Arches	33,770	Extraordinary examples of erosion in the form of giant arches, windows, pinnacles, and pedestals.
Capitol Reef	33,069	Twenty-mile-long buttressed sandstone cliff of Gothic appearance, with dome-shaped white formations superimposed on lower colorful strata.
Cedar Breaks	6,052	Great amphitheater eroded into the vividly colored Pink Cliffs formation which here has a depth of 2,000 feet.
Natural Bridges	2,650	Three natural bridges carved out of sandstone; the highest is 222 feet above the stream bed, with span of 261 feet.
Rainbow Bridge	160	Greatest of the world's known natural bridges; a symmetrical arch of salmon pink sandstone, curving in form of a rainbow; rises 309 feet from bottom of gorge.
Zion	33,921	Contains colorful Kolob Canyon and famous Hurricane Fault, notable examples of geologic phenomena.

Footnotes at end of table.

Type of area and name	Acreage[1]	Outstanding characteristics
National Forests:		
Ashley	[4]1,115,537	Uinta Mountains with 350 lakes and good trout streams. Kings Peak, 13,498 feet. Scenic canyons along the Green River. High Uintas Primitive Area.
Dixie	1,838,990	High plateaus and mountains of southwest Utah. Colorful cliffs and canyons. Numerous lakes and trout streams. Big game and waterfowl.
Fishlake	1,524,465	Mountain peaks and alpine lakes. Scenic canyons. Large deer herd.
La Sal	[5]543,442	Rugged mountain scenery. Mount Peale, 13,000 feet. Elk Ridge and Abajo Peak. Colorful canyons and Indian pueblo ruins.
Manti	796,004	Wasatch Plateau with colorful cliffs and canyons. Pictographs. Fine displays of wildflowers. Trout streams and big game.
Uinta	[6]983,980	Rugged mountains cut by picturesque canyons. Trout streams and big game.
Wasatch	[7]1,011,215	High mountain country containing numerous alpine lakes and trout streams. High Uintas Primitive Area.
NEW MEXICO		
National Monuments:		
Aztec Ruins	.26	The ruins of a great prehistoric American Indian town built of masonry and timber in the twelfth century; largely excavated and stabilized.
Chaco Canyon	18,039	Thirteen major Indian ruins without equal in the United States, representing highest point of Pueblo prehistoric civilization; hundreds of smaller ruins.
El Morro	240	"Inscription Rock," soft sandstone monolith on which are carved hundreds of inscriptions, including those of early Spanish explorers and early American emigrants and settlers; also prehistoric petroglyphs.
Gila Cliff Dwellings	160	Well-preserved cliff dwellings in four natural cavities in the face of an overhanging cliff; 150 feet high.
National Forests:		
Carson	1,115,992	Rugged mountain country; big game and turkey hunting; trout streams, lakes and hot springs; some winter sports; camping and picnic areas.
Cibola	1,795,700	Isolated wooded mountain ranges in desert country; developed winter sports, developed camp and picnic areas; big and small game hunting; some fishing; saddle-pack trips; prehistoric ruins.
Gila	2,395,583	Rugged mountains. Black Range and Gila Wilderness Areas. Famous big-game country. Hot springs. Fishing streams.
ARIZONA		
National Park:		
Grand Canyon	645,136	Tremendous mile-deep gorge, 4 to 18 miles wide, 217 miles long of which 105 miles are within the park; fantastically eroded and colored rock masses.
National Monuments:		
Canyon de Chelly	83,840	Prehistoric Indian ruins built at the base of sheer red cliffs or in caves in canyon walls; modern Navajo Indian homes and farms.
Casa Grande	473	A ruined adobe tower built by Indians who farmed the Gila Valley 600 years ago; the only prehistoric building of its particular type still standing.
Chiricahua	10,530	Wilderness of unusual rock shapes; rock strata telling story of nearly a billion years of the earth's forces.
Grand Canyon	196,051	Part of the Grand Canyon of the Colorado containing Toroweap Point with its unusual view of the Inner Gorge and recent lava dam.
Montezuma Castle	521	One of the best-preserved and most interesting cliff dwellings in the United States; built in cavern-pitted limestone cliff; original 5-story, 20-room Castle is 90 percent intact.
Navajo	360	Contains three of the largest and most intricate of known cliff dwellings—Betatakin, Keet Seel, and Inscription House.
Organ Pipe Cactus	328,162	Examples of organ pipe cactus and other desert plants found nowhere else in United States; traces of the Camino del Diablo, historic Spanish route.
Petrified Forest	85,304	Most spectacular display of petrified wood known in the world; Indian ruins and petroglyphs; portion of colorful Painted Desert.
Pipe Spring	40	Contains historic Mormon fort, also structures built by Mormons during 1869–70 and later used by private ranchers and as cattle-buying and shipping point; commemorates significant phase of westward movement by American pioneer.
Saguaro	53,669	Cactus forest containing giant saguaro unique to deserts of southern Arizona and northwestern Mexico.
Sunset Crater	3,040	Truncated volcanic cone, the upper portion so highly colored as to give rim appearance of sunset glow; lava flows and ice caves.
Tonto	1,120	Two large and well-preserved Pueblo cliff dwellings occupied during the early part of the fourteenth century by Indians who farmed in the Salt River Valley.

Footnotes at end of table.

Type of area and name	Acreage[1]	Outstanding characteristics
Tumacacori	10	A historic Spanish Catholic mission building on site first visited by Father Kino, a Jesuit, in 1691.
Tuzigoot	43	Excavated ruins of a prehistoric pueblo which flourished between 1000 and 1400 A. D.; outstanding example of large late prehistoric pueblos of the Verde Valley.
Walnut Canyon	1,642	Cliff dwellings in shallow caves under ledges of limestone, built by pueblo Indians almost a thousand years ago.
Wupatki	34,693	Contains red sandstone prehistoric pueblos built by group of farming Indians whose descendants are believed to be the picturesque Hopis.
Recreational Area:		
Lake Mead	[8]1,680,133	Lake Mead, formed by Hoover Dam, is the third largest artificial lake (volume) in the United States; recreational facilities administered by the National Park Service under cooperative agreement with Bureau of Reclamation.
National Forests:		
Apache	[9]679,432	Scenic Coronado Trail and other drives. Spruce forest and mountain meadows. Prehistoric Blue River cliff dwellings. Blue Range Wilderness Area and Mount Baldy Wild Area.
Coconino	1,750,385	Mormon Lake, largest natural lake in Arizona. San Francisco Peaks, 12,611 feet, highest in Arizona, Sycamore Canyon Wild Area. Winter sports area. Big game and turkey.
Coronado	[10]1,316,163	Catalina and Chiricahua Mountains rising abruptly from semi-desert valleys. Chiricahua Primitive Area. Rare timber species. Peccary and some big game.
Crook	1,422,629	Mountain and desert country. Scenic drives. Swift Trail, from 3,000 to 10,000 feet on Mount Graham, Coronado Trail. Blue Range Wilderness and Galiuro Primitive Areas.
Kaibab	1,865,396	Kaibab Plateau on the north side of the Grand Canyon. The virgin ponderosa pine forest is the exclusive range of the Kaibab squirrel and the range of the large deer herds.
Prescott	1,457,280	Impressive forested plateau and canyon country. Sycamore Canyon and Pine Mountain Wild Areas.
Sitgreaves	802,766	Large elk herd. Numerous archeological sites. Scenic Mogollon Rim Drive along edge of the plateau country.
Tonto	2,410,529	Famous Tonto Basin and Mogollon Rim. Superstition Mountain and Mazatzal Wilderness Areas with warm winter climate, suitable for outdoor recreation. Roosevelt, Apache, and Canyon Reservoirs. Many evidences of prehistoric occupancy.
State Parks:		
Papago	1,140	Scenic desert landscape of cactus and colorful rocks. Developments include fish hatchery, botanical garden, picnic grounds, rifle range, and large natural stadium. Administered by the Arizona Fish and Game Commission.
Saguaro	8,960	Large stand of Saguaro cactus within the boundaries of Saguaro National Monument. Administered by the University of Arizona.
State Monuments:		
Colossal Cave	640	A cave in the rugged Rincon Mountains; 1.5 miles of the cavern passages developed with walks and lights. Fine panoramic views and picnic facilities.
Fort Lowell	12	Ruins of old adobe fort, once the key outpost in the war with the Apache Indians. Fine views of the Santa Catalina and Rincon Mountains.
University Ruin	40	Extensive prehistoric Indian ruins developed and used for field work in archeology and anthropology by the University of Arizona.
NEVADA		
National Forest:		
Nevada	56,324	In Charleston Mountains. Colorful cliffs and canyons.
State Parks:		
Beaver Dam	719	Impressive scenery similar to that of southwestern Utah.
Cathedral Gorge	1,579	Long narrow valley with high perpendicular walls of grayish-tan cemented sand. Erosion in places has created isolated spires and other peculiar formations.
Kershaw Canyon-Ryan	240	Scenic cliffs eroded through lime by wind and rain.
Valley of Fire	8,752	Highly colorful basin containing odd rock formations, well-preserved petroglyphs, and petrified wood. Adjoins Lake Mead Recreational Area.
CALIFORNIA		
National Monument:		
Joshua Tree	[11]655,961	Representative stand of the rare and rapidly diminishing Joshua-tree; many other varieties of desert flora.
National Forest:		
San Bernardino	[11]804,068	San Gorgonio Mountain, 11,485 feet. Rim of the World Drive. Lakes and recreation areas.
State Parks:		
Anza Desert	408,879	Scenic desert area with several canyons containing live streams.
Mount San Jacinto	12,708	A mountain area containing magnificent stand of trees. Beautiful views over desert country.

[1] Acreage figures indicate land in Federal ownership.
[2] 144,915 acres in Colorado and 45,883 acres in Utah.
[3] 139 acres in Colorado and 160 acres in Utah.
[4] Extends into Wyoming.
[5] Extends into Colorado.
[6] Partially in Colorado River Basin.
[7] Extends into Wyoming.
[8] Extends into Nevada.
[9] Additional 889,698 acres extending into New Mexico.
[10] Additional 124,988 acres extending into New Mexico.
[11] Partially in Colorado River Basin.

The Life Zone Map

METHODS USED

It is realized that the life zone concept is open to serious criticism when used for intensive studies of small areas, and that when used for any purpose it may be open to charges of vagueness. Although the present treatment cannot hope to escape altogether such charges, an effort has been made to designate the limits of the zones as definitely as possible.

It was only after weighing all the factors involved that the decision was made to describe the Colorado River Basin in terms of life zones rather than by plant associations comparable to those used by most ecologists today. The deciding factor was that of *simplicity* for the benefit of the average nonscientific reader. It was believed that loss of critical definition, resulting from the use of these more generalized zones, would be more than compensated for, in semipopular treatise, by the reduction in number of classifications.

The life zone map of the Colorado River Basin is like nearly all maps of large areas that have ever been made, in that no matter how great has been the expenditure of care and energy to insure its accuracy, someone more familiar with local areas can discover errors of various degrees of importance. In the case of the present map, much less time was available for its preparation than originally had been anticipated, owing to circumstances beyond the control of the Colorado River Survey project. In fact, the life zone study never could have been completed if it had not been for the air surveys, which made possible a fairly comprehensive coverage of the basin within a period of only 9 months. Even so, the final product would have been much less accurate had it not been for the generous help, elsewhere acknowledged in full, of many persons having an extensive technical knowledge of various parts of the basin.

As a first step, all available botanical, zoological, and ecological publications were consulted in order to establish the average elevation boundaries of all of the life zones in the various parts of the basin. By no means all of these publications were specifically concerned with life zones, but since the major plant indicators and association equivalents of the zones have long been recognized, any information on the distribution and elevation of these indicators in various parts of the basin could be translated fairly easily into terms of life zone boundaries. These preliminary data were summarized as follows:

Life Zones—Lower Limits

[Elevations indicated in feet above sea level]

State	*Slopes*	*Upper Sonoran*	*Transition*	*Boreal*	*Authority*
New Mexico (all)	E. and West	4,700	7,500	9,000	Bailey (1913)
	N-facing	4,500	6,800	8,500	
	S-facing	5,000	8,000	9,500	
Arizona (northern)	N-facing	4,000	6,000	7,500	Bailey[1]
	S-facing	5,000	7,000	9,000	
	average elevations	below 5,000	7,000	N. 7,500 S. 9,000	Shreve (1926)

[1] Bailey, Vernon, Mammals of the Grand Canyon National Park, U. S. Department of Interior, MS.

State	Slopes	Upper Sonoran	Transition	Boreal	Authority
	E. and West		6,800	8,200	Rasmussen (1941) (Kaibab Plateau)
	N-facing		6,500		
	S-facing		7,250	8,800	
	average elevations	([2])	6,800	8,300	Hanson (1924) (Little Colorado River)
	average elevations	4,000	7,000	8,200	Jenks
Arizona (all)	average elevations	4,000	E. & W. 6,000 N. 5,000 S. 7,000	8,000 average	Nichol (1937)
	E. and West	5,560			
	N-facing	5,100	6,860		Martin and Fletcher (1943)
	S-facing	6,000	7,500		
Arizona (southern)	E. and West	4,250	6,000	9,000	Shreve (1915)
	N-facing	4,000	5,800	7,500	
	S-facing	4,500	6,300	([3])	
Western Colorado (northern half)	E. and West	base level	6,500	7,600	Cary (1911)
	N-facing	do	6,000	7,000	
	S-facing	do	7,500	8,200	
Western Colorado (southern half)	E. and West	base level	6,500	8,500	Cary (1911)
	N-facing	do	6,000	8,000	
	S-facing	do	7,500	9,000	
Utah	average elevations	3,900	E. & W. 6,800 N-facing 5,000 S-facing 7,800	6,800	Tidestrom (1925)
Utah (southwestern)	E. and West	3,500+	av. 6,200	8,000	Behle (1943)
	N-facing	3,200			
	S-facing		S-facing 6,500		
Utah (southeastern)	average elevations	3,100	7,000-7,500	8,000	Woodbury and Russell (1945)
	([4])	Lee's Ferry			Clover and Jotter (1944)
Utah (northeastern)	average elevations	base level	7,000	8,000	Graham
Nevada	average	3,900	E. & W. 6,800 N-facing 5,000 S-facing 7,800	8,800	Tidestrom (1925)
Nevada (southern)	average	([5])	8,000	9,000	Van Rossem (1936)
	E. and West		8,000		Miller (1945)
	N-facing		7,000		
	S-facing				
	average elevations	4,500	7,000	N. 7,500 S. 8,500	Bond and Jewett (1940)
California	([6])				
Wyoming (Green River area)	E. and West	base level	6,500		Cary (1917)
	N-facing	do	6,000	7,500	
	S-facing	do	7,000	8,500	

[5] Disagrees with others on U. S. Zone indicators, of Hall and Grinnel (26).
[6] Southern Arizona zone elevation data used, but checked with Grinnel (1935).
[2] Areas given instead of altitudes for this zone.
[3] None on south slope.
[4] Colorado River canyon bottom.

A transparent tracing-cloth base map of the Colorado River Basin was laid over the appropriate Regional Aeronautical Charts (Department of Commerce), which show topographic relief at 1,000-foot intervals. Provisional life zone boundaries, based on the foregoing tabulated data, were drawn on the tracing cloth, using the contours shown on the aeronautical charts as general guide lines. The topographic accuracy of these charts, which are on a scale of 16 miles to the inch, is for the most part quite high even for the more remote, unsettled regions. Contact prints of the completed tracing-cloth map, which measured 34 by 57 inches, were then taken into the field and compared, area for area, with conditions on the ground.

Nearly all of the field checking was done in a two-place light plane at altitudes varying between five hundred and three thousand feet above ground level. Planes of this type, which can cruise up to 6 hours without landing and give approximately 16 miles per gallon of fuel are receiving increasing use in many types of regional surveys and certainly will have an important and permanent place in such work.

Corrections were made as carefully as possible on the field copy of the life zone map while in the air, together with any pertinent notations. Occasionally the changes also were indicated on a set of Sectional Aeronautical Charts having a scale of 8 miles to the inch. Approximately 10,500 linear miles were flown on this reconnaissance project, which pretty thoroughly covered the basin. (Plate 2, in pocket.)

Ground studies are an indispensable supplement to air surveys and should follow them for purposes of verification, but the air surveys should come first because they provide at the outset a visual and mental grasp of the entire region which could be attained only by months or years of ground work. This is particularly true of large unfamiliar regions having a rugged and complicated topography which can be glimpsed only intermittently and at long range by ground travel, but it holds good in any type of country.

A disadvantage of air surveys is that some landscape features, such as potential development sites, appear deceptively small and are in danger of receiving inadequate consideration. With practice, however, supplemented by a checkup on the ground, one learns to make the proper correction for scale. Moreover, the required correction becomes less as one makes the surveys from lower altitudes.

Other disadvantages of air observation, such as the impossibility of making stationary observations are relative (light air craft usually being easy to maneuver in small circles), and with practice can be greatly reduced. However, the viewpoint of persons on the ground with respect to scenery, and the feeling for the type of recreational use to be made of the area by persons confined to the ground can best be appreciated while one is on the ground. This probably represents the most important advantage of ground studies over air surveys.

The air surveys showed that for many areas the provisional life zone map was surprisingly correct even in minor details, which demonstrates the accuracy of the aeronautical charts and the published ecological studies already mentioned. In a few localities actual conditions on the ground differed widely from assumed conditions on which the map had been based. This was particularly true of the Upper Sonoran Zone in the Little Colorado River Basin, which on the first draft of the map was taken from the life zone maps of Merriam (1890) and Swarth (1914) instead of from the altitude table (pp. 220 and 221), with which the maps were in conflict. These early life zone maps had been drawn up before the life zone concept had been fully developed and before detailed studies had been made of this particular basin. Apparently, these writers based the lower limit of this zone on the lower limit of the piñon-juniper belt in the basin, but subsequent studies have shown that this is not the true lower boundary of the zone in this particular area. Lack of moisture is the operating factor at the lower boundary of the piñon-juniper belt in the Little Colorado River Basin, and on the basis of temperature conditions the Upper Sonoran Zone actually extends to a much lower level in this area, as demonstrated by the presence of other Upper Sonoran life zone "indicators" of more elastic moisture requirement.

Some errors were found to have resulted through having taken data from some of the more recent vegetation type maps, but these were few. They arose, no doubt, from the physical impossibility encountered by the type mappers of covering all

of the terrain on foot, which occasionally led to misidentification of distant vegetation belts.

By far the commonest source of error in the provisional map arose from assigning, on the basis of topographic data, a higher life zone to an isolated mountain region than actually occurred there. Although special care had been taken to avoid this mistake, the warming effect of large surrounding desert regions often was even more extreme than had been anticipated. This was exemplified in the Kaiparowits Plateau, the Abajo, La Sal, Virgin, New York, Cedar, and other mountain masses.

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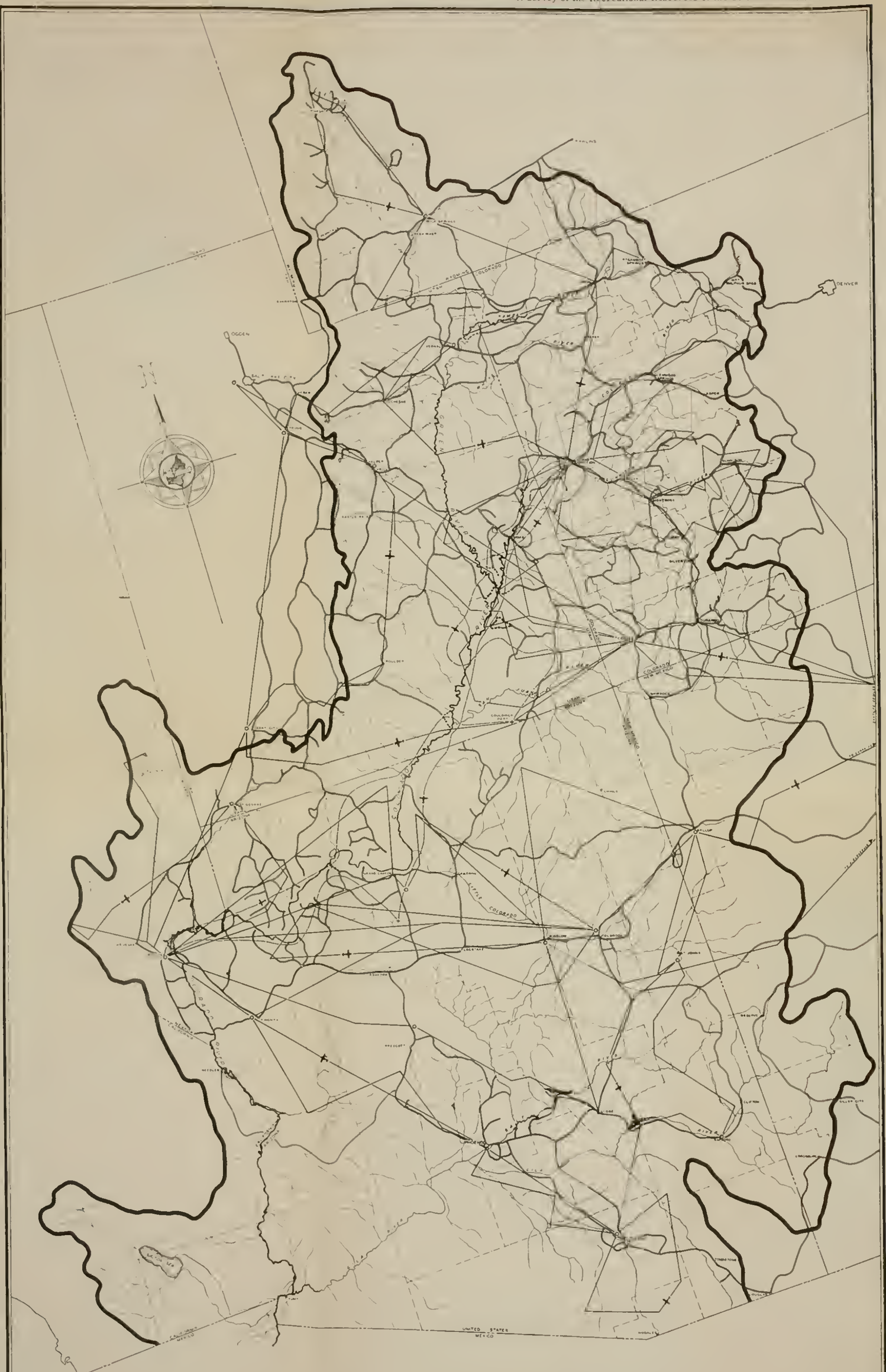

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COLORADO RIVER BASIN RECREATIONAL SURVEY

ROUTES OF AIR SURVEYS AND OTHER TRAVEL

SCALE IN MILES

NOVEMBER 1946 RS-COLO-7.1.1.7

HIGH WATER ELEVATION 4405

STREAM BED ELEVATION AT DAM SITE 4085

D & R G W RR

APPROXIMATE LOCATION U S 50 TO GRAND JUNCTION

CISCO

STATE ROAD 139

COLORADO RIVER

TO MOAB

R 24 E

R 25 E

R 26 E

T 19 S

T 20 S

T 21 S

T 22 S

T 23 S

BIG HOLE

LITTLE HOLE

WESTWATER CANYON

WESTWATER

BITTER CREEK

JONES CANYON

LITTLE DOLORES CANYON

DOLORES RIVER

UTAH

COLORADO

DATA NOT ON HAND TO SHOW RIVER ELEV 4405 IN DOLORES CANYON

RIVER ELEVATION 4405

LEGEND

REPORTED ARCHEOLOGICAL SITE
LOCATION OF DINOSAUR BONES
EXISTING PRIMITIVE ROADS

GRAPHIC SCALE

8000 0 8000 16000 24000

SCALE IN FEET

DRAWN BY JOHN E KELL JUNE 1944 - REVISED JUNE 1946

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NATIONAL PARK SERVICE

COLORADO RIVER BASIN RECREATIONAL SURVEY

MAP SHOWING

DEWEY RESERVOIR SITE

RS-COLO-7108

NEVADA
UTAH
ARIZONA
ZION NATIONAL PARK
LOWER GUNLOCK DAM SITE
VIRGIN CITY DAM SITE
ST GEORGE
HURRICANE
MT CARMEL JUNCTION
SALT LAKE CITY
TO BRICE CANYON & ESCALANTE
KAIPAROWITS PLATEAU
CROSSING OF THE FATHERS
RAINBOW BRIDGE
NAVAJO MOUNTAIN
RAINBOW LODGE
SHORT CREEK
REDONIA
PIPE SPRING NATIONAL MONUMENT
LITTLEFIELD
VIRGIN MOUNTAINS
WOLF HOLE
RIVERSIDE
GLENDALE
QUINKARET PLATEAU
PARIA PLATEAU
GLEN CANYON DAM SITE
MARBLE LODGE
JACOB LAKE
KAIBAB NATIONAL FOREST
NAVAJO INDIAN RESERVATION
MARBLE GORGE DAM SITE
PROPOSED KANAB TUNNEL
MOUNT TRUMBULL
GRAND CANYON NATIONAL MONUMENT
LAS VEGAS
LAKE MEAD RECREATIONAL AREA
PIERCES FERRY
BOULDER CITY
HUALAPAI INDIAN RESERVATION
GRAND CANYON NATIONAL PARK
COCONINO DAM SITE
CAMERON
NELSON
SEARCHLIGHT
CHLORIDE
DAVIS DAM SITE
KINGMAN
HACKBERRY
PEACH SPRINGS
SELIGMAN
ASHFORK
WILLIAMS
FLAGSTAFF
WINONA
WUPATKI NATIONAL MONUMENT
SUNSET CRATER NATIONAL MONUMENT
COCONINO NAT'L FOREST
KAIBAB NAT'L FOREST
TUBA CITY
MOENKOPI
NEEDLES
TO BARSTOW
TO LOS ANGELES
TO PHOENIX
TO WICKENBURG & PHOENIX
EXISTING
SUGGESTED
HIGH STANDARD ROAD
LOW STANDARD ROAD
UNIMPROVED
FREEWAY
GRADED OR GRAVELED IMPROVEMENT
AIRPORT
LANDING FIELD
DEVELOPMENT AREA
GRAPHIC SCALE
10 5 0 10 20 30 40 MILES
DRAWN BY JOHN E KELL
U S DEPARTMENT OF THE INTERIOR
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COLORADO RIVER BASIN RECREATIONAL SURVEY
THE GRAND CANYON REGION

OVERTON
ARIZONA
TO WOLF HOLE & ST GEORGE
DIAMOND BUTTE
TO FREDONIA
KAIBAB NATIONAL FOREST
PROPOSED KANAB TUNNEL
KANAB CREEK
HURRICANE CLIFFS
ALTERNATE
GRAND WASH
POVERTY MT
MT TRUMBULL
TUNGAR
KANAB POWER PLANT SITE
KAIBAB
MT LOGAN
GRAND CANYON NATIONAL MONUMENT
GRAND CANYON NATIONAL PARK
PIGEON CANYON
BIG SPRING WASH
MT EMMA
VULCANS THRONE
WHITMORE CANYON
PARASHONT CANYON
ANDRUS CANYON
TOROWEAP VALLEY
TUWEEP
TUMTHESAYA PT
SUPAI CANYON
KAIBAB NATIONAL FOREST
PIERCE FERRY
OAK GROVE
MT DELLENBAUGH
WAPING RANCH
PRICE BUTTE
BLUE MT
GRANITE PARK
SANUP PT
DIAMOND CREEK
DIAMOND PK
FRASIERS WELL
BRIDGE CANYON DAM SITE
MILKWEED
MUSIC MT
PEACH SPRINGS
66
AUBREY CLIFFS
CATARACT CREEK
LAKE MEAD RECREATIONAL AREA
HOOVER DAM
BOULDER CITY
TEMPLE BAR
WILLOW BEACH
COLORADO RIVER
93
TO KINGMAN
NEVADA
ARIZONA
KINGMAN 50MI
ASHFORK 62MI

	EXISTING	PROPOSED
HIGH STANDARD ROAD		
LOW STANDARD ROAD		
UNIMPROVED ROAD		
GRADED OR GRAVELED		
AIRPORT		IMPROVEMENT
DEVELOPMENT AREA		

GRAPHIC SCALE
0 5 10 20 30
SCALE IN MILES

BASIS FOR MAP TOPOGRAPHIC MAP STATE OF ARIZONA ARIZONA BUREAU OF MINES, U.S.G.S., U.S. FOREST SERVICE, BUREAU OF RECLAMATION BOULDER DAM VICINITY MAP

DRAWN BY HOWARD W YOUNG JULY - 1946

N

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COLORADO RIVER BASIN RECREATIONAL SURVEY

BRIDGE CANYON PROJECT AREA

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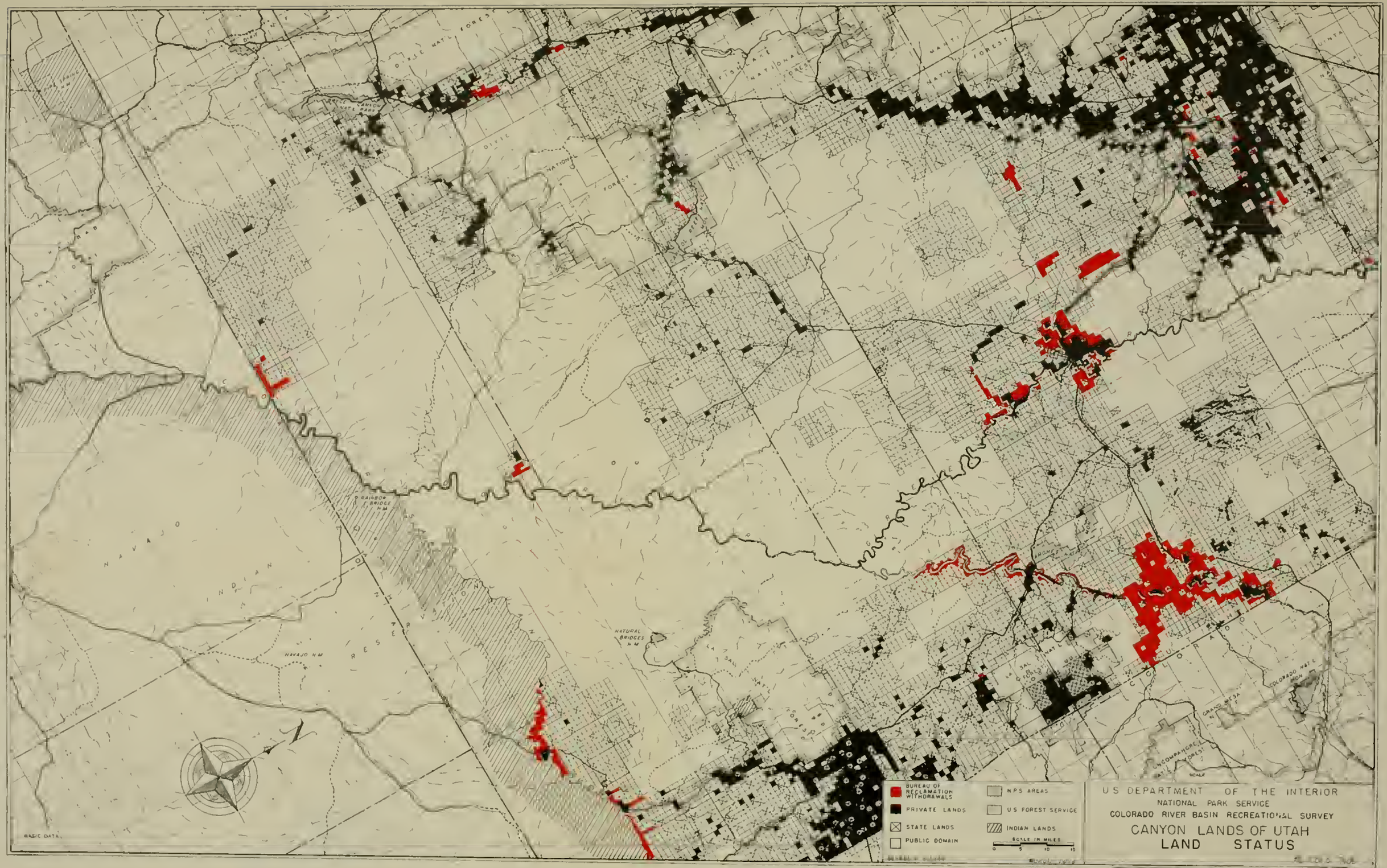

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COLORADO RIVER BASIN RECREATIONAL SURVEY

CANYON LANDS OF UTAH

SUGGESTED PLAN FOR

RECREATIONAL USE

GRAPHIC SCALE

SUGGESTED WITHDRAWAL

MAJOR DEVELOPMENT AREAS SUGGESTED

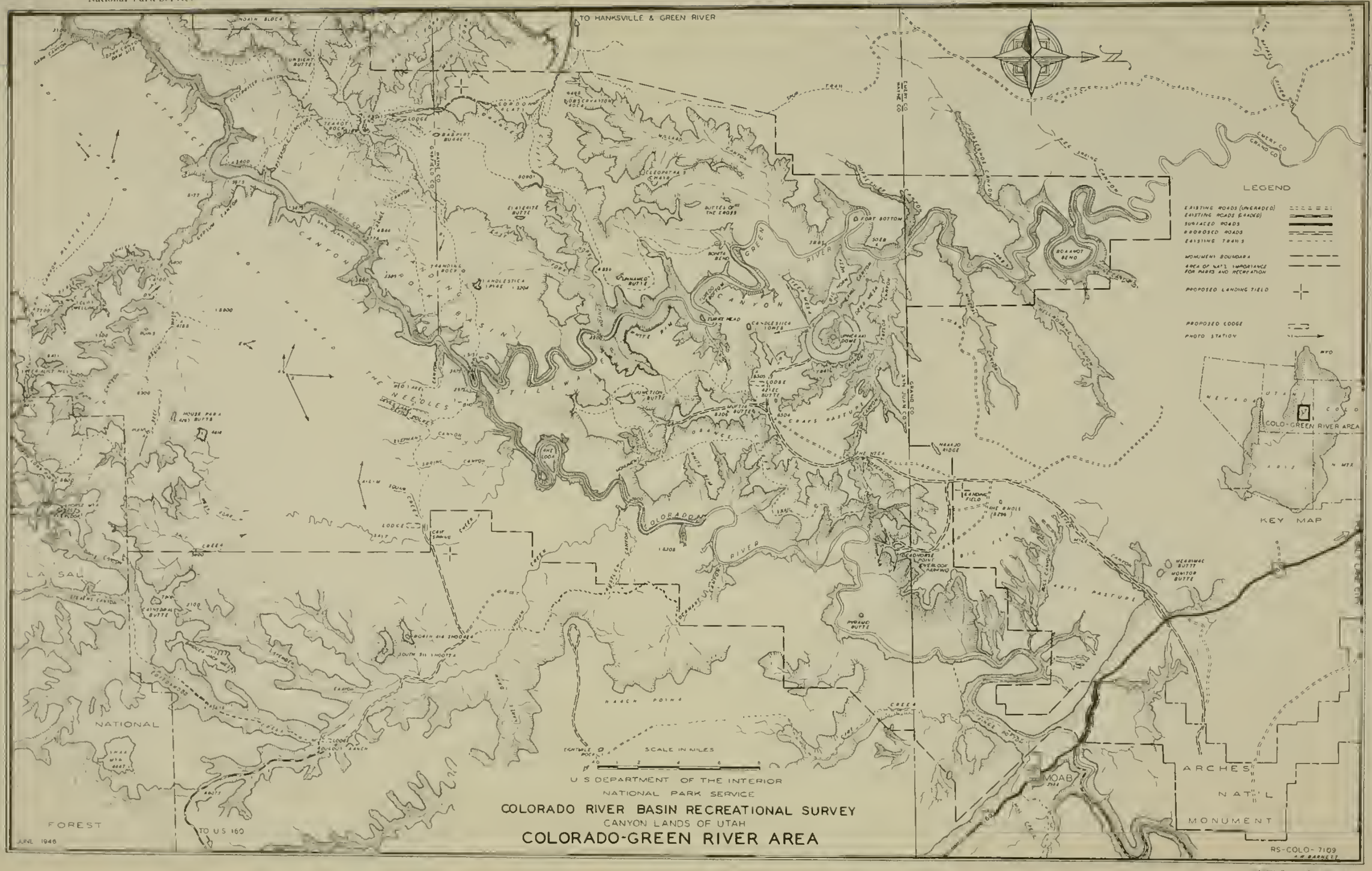
AIRPORTS (EXISTING)

LANDING FIELDS (EXISTING)

LANDING FIELDS SUGGESTED

DRAWN BY JOHN P. KELL MAY 1948

BS-COLO-7108



818771 O—49 (In pocket)

NOTE:
DAM SITES ARE APPROXIMATE.
RESERVOIR OUTLINES ARE AS OF HIGH WATER LEVEL.
WIDTH OF RESERVOIRS IN CANYONS IS EXAGGERATED.

TO GREEN RIVER WYO.
ASHLEY NATIONAL FOREST
DIAMOND PLATEAU
BRUSH
ASHLEY C.R.
VERNAL
U.S. 40
JENSEN
GREEN RIVER
UTAH COLORADO
TO ROCK SPRINGS, WYO.
LODORE CANYON OF
WILD MOUNTAIN
JONES HOLE
ISLAND PARK
WHIRLPOOL CAN.
ECHO PARK DAM SITE
HARPERS CORNER
STEAMBOAT ROCK
ECHO PARK
PATS HOLE
SPLIT MT. DAM SITE
SPLIT MT.
SPLIT MT. CAN.
HDQTRS. & QUARRY
YAMPA PLATEAU
ZENOBIA PEAK
DOUGLAS MOUNTAIN
CANYON OF YAMPA
CASTLE PARK
HARDINGS HOLE
ROUND TOP
YAMPA BENCH
GREYSTONE
TO MAYBELL
SNAKE RIVER
LILY PARK
LITTLE YAMPA RIVER
CROSS MOUNTAIN
ELK SPRINGS
U.S. 40
BLUE MOUNTAIN
MINERS DRAW

GRAPHIC SCALE
5 0 5 10 15 MI
SCALE 1" APPROX. 4½ MI.

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COLORADO RIVER BASIN RECREATIONAL SURVEY
DINOSAUR NATIONAL MONUMENT

RS-COLO-7110